ERS Staff Paper

Economic
Research
Service

Commercial
Agriculture
Division

Number 9513

Costs and Benefits of Cleaning U.S. Sorghum

Fred J. Ruppel

Costs and Benefits of Cleaning U.S. Sorghum. Fred J. Ruppel, Food and Consumer Economics Division, Economic Research Service, U.S. Department of Agriculture. Staff Paper No. AGES9513.

Abstract

There is no economic justification for a further tightening of sorghum cleanliness standards, or for separating broken kernels and foreign material into two grade factors: broken kernels (BN) and foreign material (FM). The additional cost of cleaning all sorghum to a maximum 5 percent BN, 2 percent FM level would exceed the additional benefits by $0.8 million. The additional net cost of cleaning only export sorghum would be $0.5 million. The most promising option for increasing sorghum cleanliness is to establish a new grade determining factor by summing dockage and FM percentages, and using the resulting sum as a grade-determining factor.

Keywords: Sorghum, grain quality, cleanliness, grades and standards, broken kernels, foreign material, dockage.

Washington, DC 20005-4788 July 1995

Contents

Summary

Effective June 1, 1993, the Federal Grain Inspection Service (FGIS) of the U.S. Department of Agriculture revised the U.S. Standards for Sorghum to reduce the maximum broken kernels and foreign material (BNFM) limits for U.S. No. 2 sorghum from 8 percent BNFM to 7 percent BNFM, and to institute a maximum grade limit for foreign material (FM) of 2.5 percent. There is no economic justification for a further tightening of sorghum cleanliness standards beyond what was already done in 1993, or for separating the BNFM into two grade factors: broken kernels (BN) and foreign material (FM).

Potential benefits of cleaner sorghum include increases in sorghum exports, decreased storage and transportation costs of clean grain, and revenue generated from screenings sales. The major factors affecting cleaning costs include the cost of operating cleaners, weight loss incurred during cleaning, and marketing and disposal costs of screenings. The additional cost of cleaning all sorghum to a maximum 5 percent BN, 2 percent FM (5-2) level would exceed the additional benefits by $0.8 million. The additional net cost of cleaning only export sorghum would be $0.5 million.

Country elevators dominate as the least-cost cleaning locations due to the proximity of livestock feeding centers for the disposal of sorghum screenings. A linear programming least-cost solution for cleaning all U.S. sorghum to the current standard would have 88 percent of the cleaning occurring at country elevators and 11 percent at terminal elevators. Cleaning to the 5-2 standard would lower the country elevator share to 71 percent and raise the terminal elevator share to 28 percent. Cleaning only export sorghum results in similar ratios. Port elevators seldom enter the cleaning location solution sets with more than a 1-percent cleaning share.

Increases in U.S. sorghum exports as a result of additional cleaning are not likely. Because export sorghum is almost exclusively a feed grain, cleanliness is less important than is the case for wheat, a food grain. In addition, the United States is already the world's dominant sorghum supplier, providing 80 percent of the world's sorghum exports during the past 4 marketing years, including nearly 100 percent of Mexico's imports and 60 percent of Japan's imports. Together, these two countries accounted for 90 percent of U.S. sorghum exports from 1989/90 to 1992/93. Potential growth markets include Taiwan, South Korea, and Turkey.

Policy options considered in this report for improving the cleanliness of U.S. sorghum include: (1) evaluating BN and FM as separate factors, (2) reducing the maximum BNFM or FM levels while maintaining FM as an explicit subfactor, and (3) changing the way in which dockage is reported. Splitting BN out as a separate factor is not a particularly attractive option, since the number of samples failing to pass a given grade would rise substantially even though the same cleanliness standards would essentially be maintained. Lowering the maximum allowable levels of BNFM or FM would also result in considerably higher failure rates. If dockage were reported and penalized in tenths of a percent instead of whole

truncated percents as is currently done, the weight reduction penalties could result in financial losses to sorghum industry participants of $1.54 million per year.

The most promising option for increasing sorghum cleanliness is to establish a new grade determining factor by adding dockage and foreign material percentages, and then use the resulting sum as a grade determining factor. This change would be attractive to importers because it would improve the quality of U.S. export sorghum. It would also be more attractive to sorghum handlers than would a requirement to report dockage in tenths of a percent. Although rejection rates would be greater than those encountered under the current 7 percent BNFM, 2.5 percent FM standard, the use of sophisticated blending techniques would likely result in lower additional costs than other options.

Costs and Benefits of Cleaning U.S. Sorghum

Fred J. Ruppel

Introduction

In recent years there have been concerns over the quality of grain exported from the United States versus the quality of competitors' grain. During debate on the Food Security Act of 1985, the issue of the quality of U.S. grain was raised. In an effort to gain more information for effective decisionmaking, Congress amended the act and directed the Office of Technology Assessment (OTA) to conduct a comprehensive study of the technologies, institutions, and policies that affect U.S. grain quality and to prepare a comparative analysis of the grain systems of major export competitors of the United States.[1]

The OTA study did not end the debate over grain quality, in part because it did not provide comprehensive information on the costs and benefits of cleaning U.S. grain. Some observers feel that selling grain that contains higher levels of broken kernels (BN), foreign material (FM), and dockage (DK) than that of our competitors has reduced U.S. competitiveness in the world grain market (see Glossary for definitions). Advocates of tighter U.S. grain standards related to cleanliness argue that improving grain cleanliness either will increase U.S. world market share or is necessary to maintain U.S. market share at current levels. On the other hand, many traders and handlers argue that tighter standards regarding grain cleanliness will increase marketing costs, reduce profits, and diminish U.S. price competitiveness.

In the debate of the 1990 farm legislation, Congress recognized that the information available at that time was insufficient to support either claim. Therefore, Congress included the Grain Quality Title in the Food, Agriculture, Conservation, and Trade Act (FACTA) of 1990. The Grain Quality Title requires the U.S. Department of Agriculture's Federal Grain Inspection Service (USDA-FGIS) to establish or amend grain grades and standards to include "economically and commercially practical levels of cleanliness" for grain meeting the requirements of grade U.S. No. 3 or better. The act also mandated a comprehensive commodity-by-commodity study of economic costs and benefits of cleaning grain. Studies were mandated for wheat, corn, soybeans, sorghum, and barley.

In response to this mandate, FGIS entered into a reimbursable research agreement with the USDA, Economic Research Service (ERS) to conduct the economic studies. This report has been prepared in response to the Congressional mandate. It discusses the costs and benefits (both in the domestic and international markets) of cleaning U.S. sorghum above the current level, summarizes the major findings, and presents policy implications and options to enhance

[1]The results of this study were published in three reports: (1) *Enhancing the Quality of U.S. Grain for International Trade*, OTA-F-399; (2) *Enhancing the Quality of U.S. Grain for International Trade: Summary*, OTA-F-400; and (3) *Grain Quality in International Trade: A Comparison of Major U.S. Competitors*, OTA-F-402, Feb. 1989.

What Are the Issues Being Debated?

The issues being debated that relate to sorghum cleanliness include:

- o Members of Congress, grain handlers, exporters, and producers are concerned that U.S. competitiveness in the world market may be hampered by higher levels of BN, FM, DK, and other quality differences in sorghum exported from the United States, compared with sorghum exported by major competitors.

- o The U.S. grain industry is concerned that any policy changes that require additional cleaning of sorghum would force producers or elevator operators to incur higher costs. These higher costs might not be recovered in the marketplace, and could put the U.S. grain industry at a competitive disadvantage.

- o Would the export of cleaner U.S. sorghum result in benefits in the form of price premiums (or the switch of purchases to better-grade sorghum) or expanded export sales to major importing countries? If yes, are benefits enough to compensate for the costs of additional cleaning?

U.S. sorghum cleanliness and quality competitiveness in the world market.

One feature unique to sorghum is that revised sorghum cleanliness standards have already been enacted and took effect on June 1, 1993. Thus, while reports on the other commodities focus on the costs and benefits of moving from existing cleanliness standards to new standards, this report compares the relatively new sorghum cleanliness standard with the standard that existed at the time of the legislation and with other tighter standards which could be given further consideration.[2]

Grain Sorghum Production, Consumption, and Marketing

The United States is the world's largest sorghum producer. U.S. sorghum accounted for 30 percent of 1991/92-1993/94 world production (USDA, FAS, 1994). During this period, U.S.

---

[2]In making comparisons both forward and backward, this report thus responds to both the 1990 mandate (comparing the old standard to the current standard) and the possibility of further changes from the current standard.

farmers harvested an average of 679 million bushels of sorghum per year from 10 million acres in over 20 States (USDA, NASS, 1992). U.S. sorghum production is concentrated in the Southern Plains States, with Kansas, Texas, and Nebraska dominating production. These three States account for more than 75 percent of total U.S. sorghum production.

Much of the sorghum harvested in south and central Texas during the early summer moves directly to export via Texas gulf ports or overland to Mexico. As such, sorghum is routed from country elevators to port facilities. Relatively small quantities remain in the region for local livestock consumption or move to inland terminals for long-term storage. In other production areas, the grain is assembled in country elevators with a portion subsequently routed to terminals as country elevator storage becomes inadequate to hold the fall-collected grains and soybeans. Terminal and sub-terminal operations in Kansas, Texas, and Nebraska are involved in multicar rail shipments to Texas gulf and Pacific Northwest ports, as well as grain-deficit regions in Texas and California. Much of the sorghum produced in the Mississippi River Valley is transported to Louisiana gulf ports for export and, as such, is routed through river elevators (barge loading facilities).

Grain sorghum is primarily used as a concentrate for livestock and poultry feed in the United States. Sorghum production in the Southern Plains offers the cattle feeding industry an important source of feed grain. Increases in the feedlot industry in this region have coincided with growth in the sorghum industry (Jackson, et al.). Growth in the poultry industry contributed to a modest increase in sorghum production in the South in the early 1980's (Grant and Cooke). Approximately two-thirds of total annual disappearance goes to livestock and poultry feed. Livestock consumption amounts to an estimated 96 percent of total domestic sorghum disappearance, with the remainder for food, alcohol, seed, and industrial uses (USDA, NASS, 1992). Approximately one-third of the annual sorghum harvest is exported (USDA, NASS, 1992).

In general, U.S. sorghum exports are not for human consumption except in developing regions in Africa and Asia. It is widely used as animal and poultry feed in the more developed countries. During the first part of the 1990's, the United States was the world's leading sorghum exporter, accounting for 76 percent of total exports. Argentina (14 percent) and People's Republic of China (5 percent) accounted for most of the non-U.S. world sorghum exports (USDA, FAS, 1989-93). Japan and Mexico are the world's major sorghum importers. Mexico averaged 44 percent of the world's total sorghum imports during 1990/91-1993/94, while Japan averaged 40 percent (USDA, FAS, 1989-93). Together, these two countries accounted for nearly 90 percent of U.S. sorghum exports during this period (USDA, FAS, 1989-93).

Structure of the Study

In the debate over the need for tighter cleanliness standards, the terms "cleanliness" and "quality" are sometimes confused. In the second section, the definition of cleanliness and its role is examined within a much broader context of sorghum quality. The third section focuses on available options and current practices of delivering cleaner sorghum at each market

location. These options include changes in production and harvesting practices on farms, as well as mechanical cleaning and blending at farm and elevator points.

In section four, the procedures used in estimating costs and benefits of cleaning sorghum are presented. Costs of cleaning sorghum to four different grade standards at each location in the marketing channel are calculated using economic engineering studies. Per-bushel fixed and variable costs generated by the economic engineering approach were then used in a linear programming (LP) model to measure the increase in sorghum marketing system costs that would result with implementation of tighter standards. The LP model also computed the optimal locations within the market channel for additional cleaning investment and identified regions where the additional investment in cleaning capacity would be most economical.

The fifth section examines the determinants of costs and benefits of cleaning sorghum and the rationale behind each determinant. Section six presents estimates of the costs and benefits of cleaning sorghum to four cleanliness levels under two scenarios and using three sorghum price levels. Cleaning locations and additional investment necessary to meet alternative standards are also presented. Finally, the last two sections of this report present implications and policy options to enhance U.S. sorghum cleanliness and quality competitiveness in the world market. The appendices present more detailed information about the data and study results.

Role of Cleanliness in Sorghum Quality

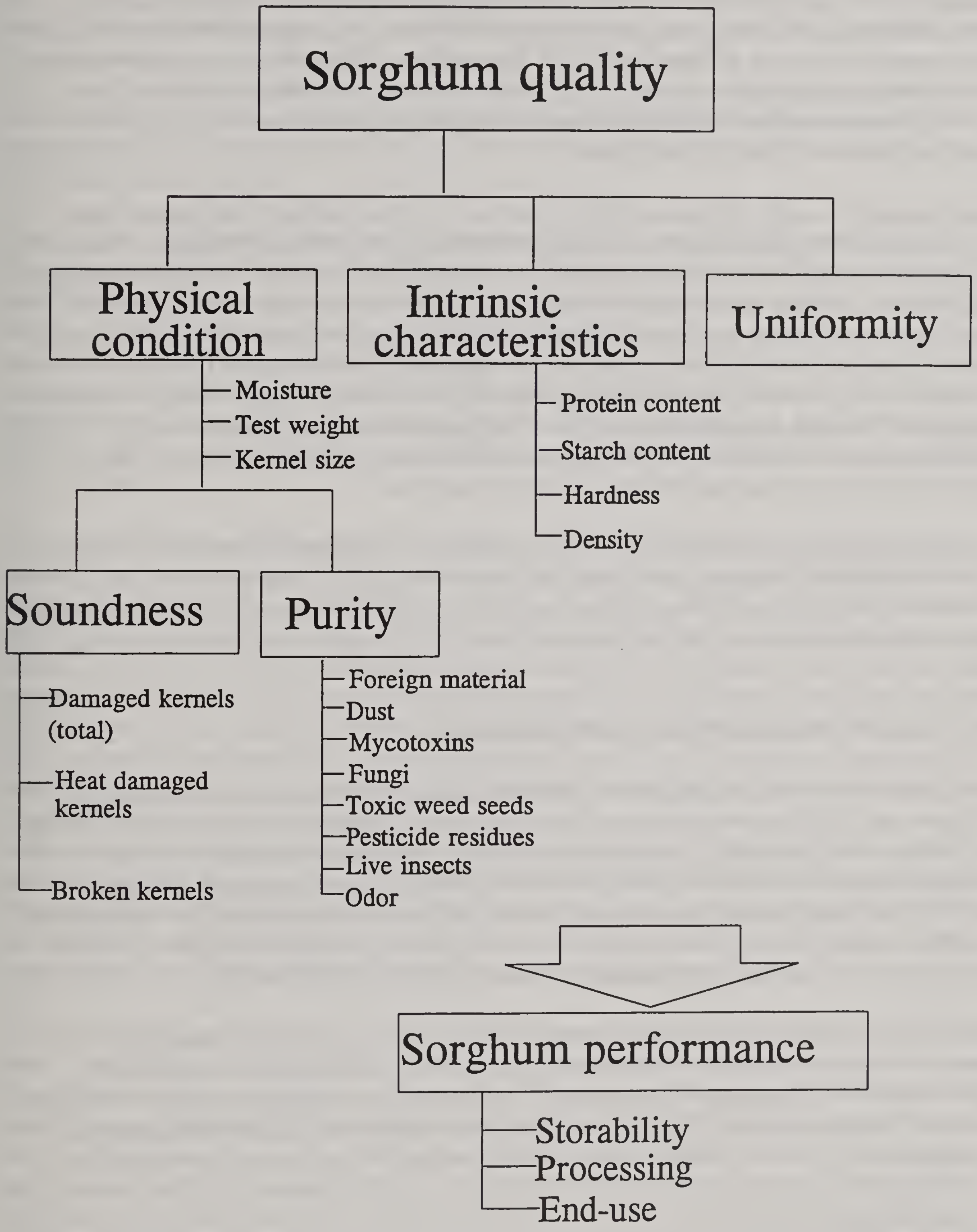
Sorghum quality has three dimensions: (1) physical condition, including soundness and purity, (2) intrinsic characteristics, and (3) uniformity (fig. 1).[3] Soundness refers to the physical defects and damage in sorghum kernels. These factors include total damaged kernels, heat damaged kernels, and broken kernels (see Glossary). Purity measures the quantity of nonsorghum material. Its components include foreign material, dust, mycotoxins (especially aflatoxin), fungi, toxic weed seeds, pesticide residues, live insects, and odor.[4] Other physical characteristics include moisture, test weight, and kernel size. Moisture is not a grade-determining factor, but is a very important quality characteristic for sorghum. Grain with high moisture levels is more susceptible to mold, bacteria, and sprout deterioration during storage (Watson). Intrinsic characteristics are the structural and biological attributes inherent in sorghum. As an energy feed, starch content is sorghum's most important intrinsic characteristic. Finally, uniformity is the degree of variation in the physical and intrinsic characteristics. In general, buyers prefer uniform sorghum quality.

---

[3]Many of these sorghum quality characteristics are similar to those for corn. See the ERS domestic corn cleaning report for details (Lin and Lin).

[4]Dust is defined by FGIS as a component of FM at export locations in U.S. sorghum grades and standards. However, its physical and chemical properties differ from other FM components. In addition, many of the non-FM components could be considered as FM in U.S. grades and standards.

Figure 1. Sorghum quality dimensions



Source: Adapted from the ERS domestic corn cleaning study.

Defining Cleanliness in Sorghum Quality

Cleanliness is only one of many characteristics which determine overall sorghum quality. Sorghum cleanliness, for the purposes of this report, refers to the measured levels of broken kernels, foreign material, or dockage present in the sorghum. These levels can be recorded as separate factors, as subfactors, or jointly (e.g., broken kernels and foreign material). The factor levels are assessed by FGIS inspectors who sample the grain according to rigorous scientific procedures (USDA, FGIS, 1990a).

Dockage (primarily weeds, stems, and dirt) is measured as that portion of the sample that passes through all three screens into the bottom collection pan of a Carter Dockage Tester. Broken kernels are those materials that collect in the third pan. The BN level is calculated as the weight of the brokens divided by the original sample net of dockage. Finally, foreign material is calculated as the sum of two components: (1) the ratio of the weight of the material that collects in the top pan relative to the dockage-free sample; and (2) the percentage of foreign material hand-picked by the inspector from a 30-gram sample of filtered sorghum taken from the second collection pan. This second component includes an adjustment factor for the BN and FM already removed in the mechanical process. FM typically includes chaff, insects, and other nongrain particles.

The amount of BN, FM, and DK present in U.S. sorghum is affected by harvesting practices, drying and conditioning methods, and handling methods commonly used in the U.S. grain production-marketing system. Cleaning is expected to lower the levels of all three factors in varying degrees, depending on the methods employed and the screens used in the cleaning devices.

Recent Changes in Sorghum Grain Quality Standards

Sorghum grades and standards help buyers determine quality and cleanliness, in addition to facilitating trade. The grades and standards deal mainly with physical characteristics including broken kernels, foreign material, heat-damaged kernels, total damaged kernels, and test weight. There are four numerical grades, U.S. No. 1 to U.S. No. 4, as well as a sample grade. U.S. No. 2 sorghum is the dominant U.S. export grade, accounting for 99.7 percent of U.S. sorghum exports during 1990-92. U.S. No. 1 sorghum amounted to 0.2 percent of the samples, and only 0.1 percent were graded U.S. No. 3 (USDA, FGIS, 1993).

Cleanliness is reflected in the U.S. grain grades and standards for sorghum through the inclusion of BNFM as a grade-determining factor, with FM as a subfactor. In addition, dockage is recorded in truncated whole percents, and the seller is subject to penalty when the DK level is 1 percent or more.[5] BN and FM have historically been combined in sorghum grading standards. Until recently, the combined BNFM limit was 4 percent for U.S. No. 1

---

[5]Dockage is certificated in whole percentages, with fractional percentages disregarded. For example, dockage of 1.00 to 1.99 percent is recorded as 1.0 percent.

sorghum, 8 percent for U.S. No. 2, 12 percent for U.S. No. 3, and 15 percent for U.S. No. 4 (table 1). Effective June 1, 1993, FGIS enacted new standards that lowered the BNFM limits on U.S. No. 2 sorghum by 1 percentage point and U.S. No. 3 and U.S. No. 4 by 2 percentage points, with no change in the U.S. No. 1 BNFM limits (table 1). In addition, grade limits for foreign material were instituted as a subfactor of BNFM. These FM grade limits were set at 1.5, 2.5, 3.5, and 4.5 percent for U.S. No. 1 through U.S. No. 4 sorghum, respectively. Given that U.S. No. 2 is the dominant sorghum export grade, the effective change is a movement from 8 percent BNFM with no limits on either BN or FM to 7 percent BNFM with a 2.5-percent limit on FM.

The decision to change sorghum grading standards was the result of a long process of research, consultation, hearings, and discussion. The process began in 1985/86 when the U.S. grain industry held a series of grain quality workshops to discuss grain quality. A published consensus report representing more than 75 grain trade and producer group leaders included two recommended changes to the (old) sorghum standards (North American Export Grain Association). The first was a reduction in the amount of brown sorghum allowed in yellow sorghum from 10 percent to 3 percent. Brown sorghum is a high-tannin grain that can cause as much as a 30-percent reduction in feed efficiency, compared with yellow sorghum (USDA, FGIS, 1992a).

The second recommended change was a separation and reduction in the combined BNFM limits. The report's recommended limits were 2 percent BN, 1 percent FM for U.S. No. 1 sorghum; 4 percent BN, 2 percent FM for U.S. No. 2; 6 percent BN, 4 percent FM for U.S. No. 3; and 8 percent BN, 6 percent FM for U.S. No. 4 (down from 4, 8, 12, and 15 percent BNFM, respectively). After a lengthy process of consultation and input from many interested parties, FGIS modified the recommendations by relaxing the BN standards and tightening the FM standards. Their proposed rules change, published in the *Federal Register* on April 2, 1991, called for 3 percent BN, 1 percent FM limits for U.S. No. 1 sorghum; 5 percent BN, 2 percent FM for U.S. No. 2; 7 percent BN, 3 percent FM for U.S. No. 3; and 9 percent BN, 4 percent FM for U.S. No. 4. During the ensuing 60-day comment period, FGIS received 29 comments from various segments of the sorghum industry (see USDA, FGIS, Dec. 1992). After taking these comments into consideration, FGIS further modified its proposed changes by establishing FM as a subfactor of BNFM rather than completely separating the factors, and by relaxing the FM limits somewhat from the proposed levels (table 1). Notification of the rules change was published in the *Federal Register* on December 14, 1992.

Three other changes in the U.S. standards for sorghum were also announced by FGIS at that time to take effect on June 1, 1993. These included a reduction in limit of brown sorghum contained in yellow sorghum from 10 percent to 3 percent as recommended in the consensus report; name changes of "yellow sorghum" to "sorghum" and "brown sorghum" to "tannin sorghum"; and revisions in the definitions of all classes of sorghum. A proposal to change the reporting methods on dockage from rounding down to the whole percent (disregarding fractions) to reporting dockage in tenths of a percent met with a good deal of opposition. FGIS elected to investigate alternative options regarding dockage prior to possible action at a later date.

Table 1--Grade requirements for sorghum, numerical grades

a) Limits prior to June 1, 1993

Grade	Minimum test weight per bushel	Maximum limits of: Total damage kernels	Heat damage kernels	Broken kernels and foreign material (BNFM)
	Pounds	*Percent*		
U.S. No. 1	57	2	0.2	4
U.S. No. 2	55	5	0.5	8
U.S. No. 3	53	10	1.0	12
U.S. No. 4	51	15	3.0	15

b) Limits after June 1, 1993

Grade	Minimum test weight per bushel	Maximum limits of: Total damage kernels	Heat damage kernels	BNFM	FM
	Pounds	*Percent*			
U.S. No. 1	57	2	0.2	4	1.5
U.S. No. 2	55	5	0.5	7	2.5
U.S. No. 3	53	10	1.0	10	3.5
U.S. No. 4	51	15	3.0	13	4.5

Source: USDA, FGIS, Apr. 1991, Dec. 1992.

Sorghum Cleanliness in the United States

Virtually all U.S. sorghum is marketed as U.S. No. 2 or better. Over the past few years, U.S. exports of sorghum have averaged well within the current cleanliness standards (table 2). In fact, a majority of sorghum exports under U.S. No. 2 contract actually met the cleanliness standards for U.S. No. 1. During 1989-92, the combined BNFM level averaged 1.6 percentage points below the current 7-percent maximum for that grade. Average FM levels of 1.6 percent were comfortably below the 2.5-percent standard. Broken kernels have averaged 3.7 percent, while dockage has averaged 0.3 percent. In addition, test weights have averaged 3.1 pounds above the minimum of 55 pounds and damaged kernel levels have been less than 40 percent of the maximum of 5 percent.

FGIS records of sorghum inspections during 1987-91 indicate that 96.8 percent of the samples graded in domestic markets met the old standards of 8 percent BNFM for U.S. No. 2 sorghum (table 3).[6] Nearly 100 percent of export samples met the U.S. No. 2 standards during the same time period. Of more than 2,000 samples, only one exceeded the 8-percent BNFM limit for U.S. No. 2 sorghum. The mean of these export samples was 5.4 percent BNFM, with 90 percent of the samples at 6.6 percent or below (fig. 2).[7] Only 4 percent of the samples exceeded 7 percent BNFM, and only 0.9 percent were greater than 7.5 percent BNFM. Some of these samples very likely included sorghum that had tested U.S. No. 3 (because of BNFM exceeding 8 percent) prior to blending with cleaner sorghum. Unpublished information from a 1991 National Grain and Feed Association grain elevator survey indicates that only about 6 percent of the 1990 sorghum crop was cleaned.

Tighter standards result in higher "failure rates" (i.e., lower percentages of samples achieving a certain grade level). If the current standards (7 percent BNFM, 2.5 percent FM) were applied to the 1987-91 domestic data set, 10.8 percent of the samples would have failed to meet both of the new criteria for U.S. No. 2 sorghum (table 3). The 1-percentage-point tightening of the BNFM standard results in an increase from 3.2 percent of the samples failing at 8 percent BNFM to 8.3 percent failing at 7 percent BNFM. An additional 5.6 percent of the samples were over 2.5 percent FM, and 3.0 percent would have failed on both criteria. Although exports would have fared somewhat better under the current standards (8.6 percent failure rate), with further tightening of the BN and FM standards, the export failure rates are substantially higher than are the domestic failure rates (table 3). However, because of the widespread use of sophisticated blending methods, these failure rates are certainly inflated over what they would have been had the new standards actually been in place.

---

[6]As a quality control measure, FGIS reexamines samples of grain already graded by their inspectors. Assumptions employed in this study use only the original grade report, since this information is the basis for grain trades. These domestic samples are the result of requests submitted by grain handlers and are not the result of a random sampling process. Accordingly, factor averages may not reflect the true state of domestic sorghum cleanliness. These sample data differ from those in the New Crop Quality Survey.

[7]This mean is only slightly higher than the 4.6 percent BNFM in sorghum inspected for domestic sales.

Table 2--U.S. No. 2 sorghum export quality, 1989-92

Item	Standard		Mean values			
	Old	Current	1989	1990	1991	1992
			Pounds			
Test weight	55.0	55.0	58.2	57.8	58.1	58.3
			Percent			
Damaged kernels	5.0	5.0	2.4	1.9	1.7	1.8
Heat damage	.5	.5	0	0	0	0
Broken kernels and foreign material	8.0	7.0	5.6	5.4	5.4	5.1
Foreign material	n.a.	2.5	1.5	1.7	1.7	1.6
Broken kernels	n.a.	n.a.	4.1	3.7	3.7	3.4
Dockage	n.a.	n.a.	.4	.3	.3	.3

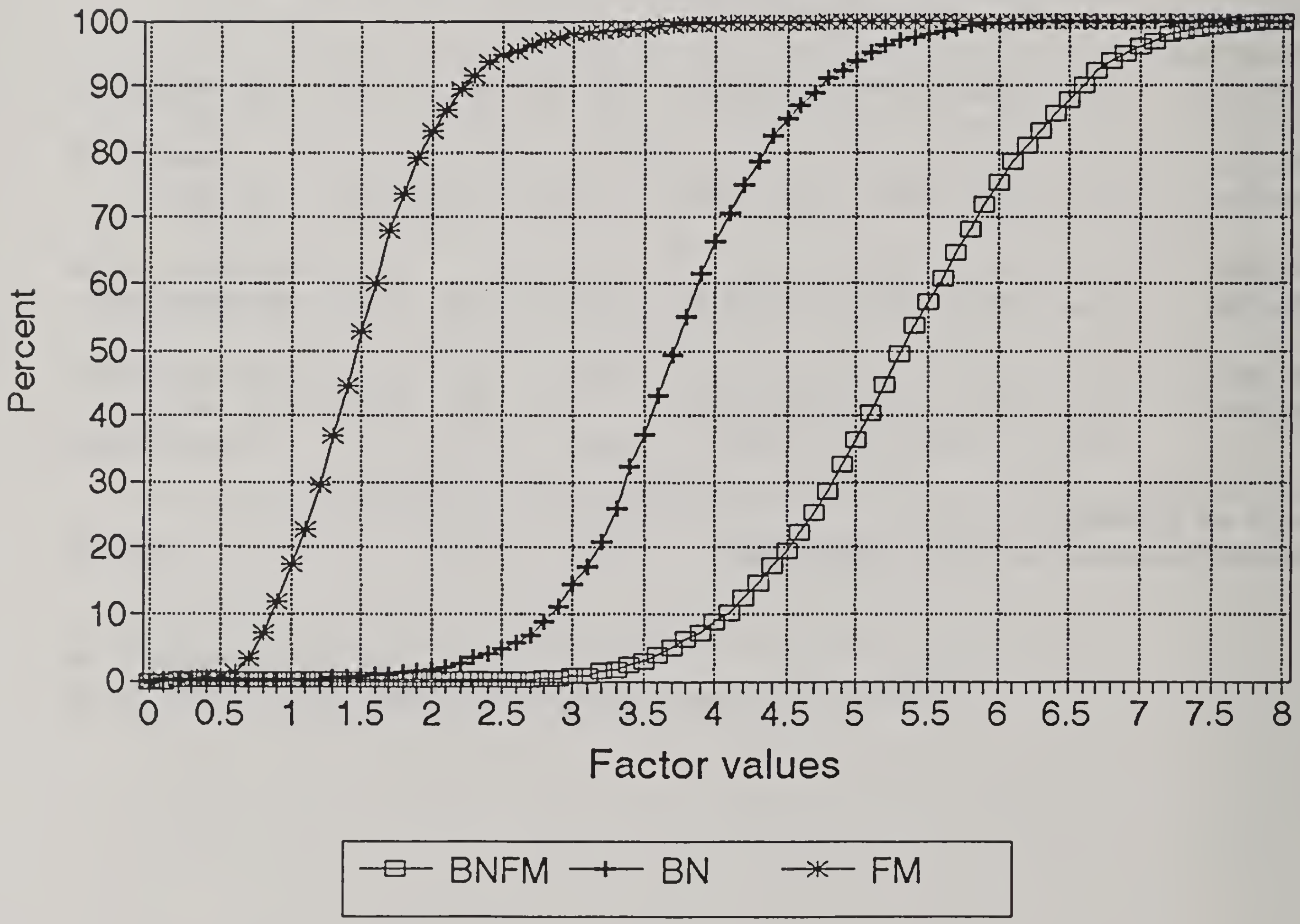
n.a. = not applicable.
Source: USDA, FGIS, *Grain Exports: Quality Report*, 1991 and 1992.

Table 3--Failure rates for alternative U.S. No. 2 sorghum standards using 1987-91 data

Standard	Domestic samples					Export samples				
	BNFM	BN	FM	Both	Total	BNFM	BN	FM	Both	Total
	Percent									
8% BNFM	3.2	n.a.	n.a.	n.a.	3.2	0.1	n.a.	n.a.	n.a.	0.1
7% BNFM, 2.5% FM	8.3	n.a.	5.6	3.0	10.8	5.2	n.a.	4.5	1.2	8.6
5% BN, 2% FM	n.a.	10.8	10.0	1.3	19.6	n.a.	8.3	14.9	.8	22.5
4% BN, 2% FM	n.a.	28.2	10.0	3.7	34.5	n.a.	41.7	14.9	6.2	50.4
4% BN, 1% FM	n.a.	28.2	38.5	13.7	53.0	n.a.	41.7	83.0	38.2	86.5

n.a. = not applicable.
Source: Calculations using USDA, FGIS data.

Figure 2. Cumulative frequency distributions, 1988-92 export sorghum



The 1987-91 FGIS inspections of domestic samples indicate a fair amount of quality consistency among the major producing States. The BNFM level in the three largest producing States (Kansas, Texas, and Nebraska) all ranged between 4.4 and 4.7 percent, with FM ranging between 1.0 and 1.2 percent, and BN between 3.3 and 3.7 percent.

Blending

Blending is the practice of mixing different lots of grain that possess different attributes or grades so as to obtain a desired combined effect. Most commonly, grain that tests marginally into a lower grade can be combined with cleaner grain to meet standards for the next higher grade. For example, sorghum that contains 7.2 percent BNFM and 2.0 percent FM would grade out as U.S. No. 3 (assuming other factors passed grade). This U.S. No. 3 sorghum could be combined in equal quantities with sorghum that contained 6.0 percent BNFM and 1.8 percent FM to obtain combined factor ratings of 6.6 percent BNFM, 1.9 percent FM, thereby grading out as U.S. No. 2. Thus, sorghum that would have been "discounted" as U.S. No. 3 is now able to obtain the higher U.S. No. 2 price.

Blending can occur at any point in the marketing channel where the grain handler has the necessary equipment to effectively combine two separate streams of grain. Typically, this requirement is fulfilled if the capability exists to channel two storage bin streams simultaneously into one receiving outlet. For the most part, this requirement makes onfarm blending unlikely, but allows for blending at country elevators and beyond. Although country elevator operators typically do not have the training or sophisticated equipment necessary to accurately measure BN or FM factor levels, they are able to make informed decisions about whether to blend grain (and incur or avoid potential grade price discounts) based on their years of experience in handling grain. However, blending is more common at terminal and export elevators, where inhouse inspection capabilities and grading skills are more abundant.

Options for Cleaning Sorghum within the Production-Marketing System

There are several aspects of production and marketing practices for sorghum that contrast with wheat and corn. First, like wheat and unlike corn, artificial drying of sorghum is rare. Corn is typically harvested at a moisture content level of 18 to 29 percent. Because discounts are generally applied for moisture content above 15 percent, most corn is artificially dried (Lin and Lin). By contrast, sorghum is harvested at relatively low moisture levels (usually around 13 to 18 percent), and drying is the exception rather than the rule. The 1990-92 moisture content for U.S. sorghum exports averaged 13.3 percent. Second, again like wheat and unlike corn, the amount of broken kernels increases only slightly with additional handling as sorghum moves through the marketing system. For corn, the drying process creates a more brittle outer shell, resulting in increased breakage each time the grain is handled. Because wheat and sorghum are seldom dried artificially, they are less susceptible to this type of breakage. Finally, livestock feeding is the dominant end use for U.S. sorghum. Like corn, cleanliness in sorghum is not as critical for feeders and feed manufacturers as it is for wheat flour millers or for corn dry millers and wet millers.

A number of options for cleaning sorghum are available to sorghum producers and handlers. Sorghum may be cleaned on farm during harvest (with proper combine adjustment) or at country, terminal, or port elevators during unloading, storage, or loading. If cleaned onfarm or at country elevators, storage, handling, and transportation costs are reduced throughout the remainder of the marketing system. However, the low volume handled (on average) at these locations and correspondingly higher cleaning costs could offset these cost reductions, making cleaning (when needed) more economical at a terminal or port elevator. In addition, if grain is cleaned during storage at country and terminal elevators, an elevator is able to use a smaller capacity cleaner (by cleaning more frequently throughout the year). This option, however, requires additional movement of the grain to the cleaner and back to storage, a process that increases cleaning costs and grain handling loss. Port elevators have limited storage capacity and must move grain rapidly through the facility, and hence, seldom clean grain during storage.

Onfarm

Farmers can deliver cleaner sorghum through altered production and harvest methods, or through the use of mechanical cleaners to reduce BNFM. Sorghum production practices affect the quality of the harvested grain, both in level of brokens and foreign matter. Varietal selection could reduce grain broken during harvest and handling by choosing harder kernel varieties. Most current varieties have a soft grain genetic background that increases the quantity of brokens. There are varieties with harder kernel characteristics that are less prone to breakage. Unfortunately, research indicates a negative relationship between the level of kernel hardness and relative digestibility of the grain, a feature that would lower the feed value for sorghum (Riggs). Harder kernels require grinding before feeding to enhance digestibility. This added processing imposes an added cost to the buyer of sorghum. Relative digestibility of 61 varieties of sorghum ranged from 44 to 137 percent of the value of corn, with a mean of 90 percent (Riggs). Softer endosperm types have higher digestibility relative to corn. Legislation values sorghum at 95 percent of corn based on feeding value.

Producers can alter production practices to reduce FM through additional tillage and crop rotations. Increased cultivation can reduce weed problems and lower the herbicide levels needed for weed control. However, additional cultivation involves additional expense and contributes to other problems such as soil erosion. Crop rotation can be used to interrupt the life cycle for some pests and reduce the incidence of weeds, insect pests, and diseases. Crop rotation is effective in reducing chemical costs and raising yields. Many producers in hotter, dryer regions who formerly followed wheat with soybeans have switched to sorghum because of its higher drought resistance (Lin and Hoffman). Wheat-sorghum double-cropping can also be used to reduce FM. Farmers who double-crop wheat and sorghum often include single-crop soybeans in the rotation because of soybeans' nitrogen fixation contribution to the soil relative to other rotations.

The BNFM level also can be reduced through increased chemical applications, including herbicides, insecticides, and fungicides. Although increasing chemical applications may lower FM levels, it also raises production costs. The viability of increasing chemical applications to

reduce FM in sorghum is controversial and will continue to be because of public concerns about nonpoint water pollution and pesticide residues on food.

Altering production practices to reduce field weeds and insect infestation may lower FM levels. However, the average FM level for the 1987-91 domestic samples was only 1.1 percent, less than one-fourth of the combined BNFM level of 4.6 percent. Since most of the BNFM is broken kernels, little gain in cleanliness can be obtained by altering production practices. With current low levels of FM, it would be very expensive to achieve any substantial reduction in BNFM levels. The low FM content in sorghum makes changes in production practices an ineffective option for lowering the BNFM level.

Proper setting of combines is essential to harvesting clean grain. Improper adjustments in a combine generally lead to either an increased loss of usable grain in the field or an excess of BNFM in the threshed grain. Seed producers in the High Plains area of Texas often harvest sorghum with BNFM levels well below the current or even proposed U.S. No. 2 quality levels using rotary combines instead of cylinder combines. Rotary combines are extremely effective in reducing the amount of broken kernels. Conventional combines with properly adjusted cylinders and sieves can also clean sorghum during harvest. Lowering the combine cylinder and ground speeds decreases the BNFM level in the threshed grain, but this slowdown may increase harvest time and costs. No research results on sorghum were found relating combine adjustments or harvest speed to measured levels of foreign matter or broken kernels in the harvested grain. An Australian-developed cleaner mounted on the combine cleans grain during harvest (Fridirici et al.). The material removed is stored in a separate bin on the combine and can be used on the farm or sold as screenings. The advantages of this cleaner include a cleaner grain at harvest, a reduction in the amount of weed seed being returned to the field, and less of a need for slower speed during harvest. The increased cost for the combine is the disadvantage.

The market provides an incentive to the seed producer to develop and market a higher quality product. This is not the case for the cash market for sorghum. Unless the marketing system reflects a reward for cleaner grain, there is no incentive for the producer to undertake changes in production practices or harvesting methods to achieve a cleaner harvested crop.

Because of the costs involved in altering production and harvesting methods, cleaning sorghum mechanically may be a more cost-effective option for reducing the BNFM level on the farm (Hill, Bender, and Beachy).[8] Instead of applying these changes to the entire sorghum crop, mechanical cleaning permits producers to selectively clean sorghum only if the

---

[8]Cleaning sorghum refers to the process of removing broken kernels, foreign material, and dockage from the grain. This removal process can be accomplished by screens, aspirators, and disc-cylinder cleaners (U.S. Congress, Office of Technology Assessment; Adam and Anderson). An aspirator is a device that draws a column of high velocity air across a flowing grain stream to separate low density materials (foreign material, chaff, and insects) from the grain kernels by weight differential. A screen cleaner is a series of angled perforated plates or wire screens that separate the grain from particles that are larger or smaller than the grain kernels. A disc-cylinder cleaner removes dockage on the basis of particle shape and length. See Glossary for more details.

Onfarm Survey

Two forms of questionnaires were sent in 1991--a short postcard and a long-form survey. The postcard survey was sent to 2,500 members of the National Grain Sorghum Producers Association. Similar surveys were sent to other grain producers, who also grow sorghum, through their organizations. Of the 45 postcards returned from members of the National Grain Sorghum Producers Association, 11 percent of the respondents owned cleaners. The long form was sent to 80 sorghum producers owning cleaners, including growers who are members of other grain grower organizations, to obtain more in-depth information about cleaning. Responses from 10 producers were received.

The short form covers questions about (1) grains produced, (2) the level of BNFM for sorghum at harvest and cleanliness levels for other grains, (3) viability of delivering cleaner grains (at no or little additional cost) by changing harvesting and handling practices, and (4) ownership of cleaners.

The long form asked questions dealing with (1) purpose of cleaning, (2) extent of cleaning, (3) types of cleaners used, (4) alternative strategies to reduce BNFM, (5) premiums and discounts for BNFM, and (6) storage and sales of screenings.

BNFM level is excessive. Only 11.1 percent of sorghum producers answering the farm survey owned cleaning equipment (see "Onfarm Survey" box). This percentage is comparable with barley producers (9.1 percent), but is less than half as large as wheat producers (24.3 percent) and less than one-quarter the percentage of corn producers (45.8 percent) who own cleaners. Although portable cleaners are available for onfarm use, harvest may be slowed due to their limited capacity. Thus, the expense of a portable onfarm cleaner might not be economically justifiable to a producer considering other onfarm options for cleaning sorghum.

Country Elevators

Over 800 country elevators responded to the National Grain and Feed Association (NGFA) Survey (see "Grain Elevators" box and appendix A). These elevators reported an annual average volume per elevator of over 4.5 million bushels (MB) of grains and soybeans during 1990. Only 4 percent of their reported volume was sorghum. A total of 96 country elevators reported handling sorghum as a major part of their operation and responded to the detailed sorghum questionnaire. These elevators averaged a total annual volume of 2.3 MB of all grains. Over one-third of their volume was sorghum. Slightly over one-third of these elevators reported owning cleaning equipment. Similiarly, almost one-third could add cleaning capacity to existing facilities. Less than 4 percent reported cleaning sorghum, at an average cost of 2 to 4 cents per bushel in 1990.

Grain Elevators

Characteristics of U.S. grain elevators were obtained from a 1991 survey conducted by the National Grain and Feed Association (NGFA). Survey questionnaires were sent in April 1991 to 6,237 elevators registered by the Agricultural Stabilization and Conservation Service, USDA. Elevator operators were asked to report general characteristics of their elevator as well as detailed characteristics of the major crops they handled. Respondents to the NGFA survey (nearly 900) included 110 elevators that handled sorghum and responded to a detailed sorghum questionnaire. The sorghum section covers questions about (1) source of sorghum, (2) BNFM levels received, removed, and costs associated with removal, (3) premiums and discounts for BNFM, (4) sorghum storage practices, (5) storage and sales of screenings, and (6) rationales for cleaning and not cleaning. The reporting elevators were classified as country, terminal, and port. Characteristics of these facilities are reported in appendix table A-1. These characteristics make possible the estimation of grain cleaning costs by type of facility. Since all elevators handle multiple grains, cleaning capacity and cost must take into account the use of this equipment on all grains handled.

Sorghum cleaning in country elevators is much less common than corn cleaning. The survey results indicated that nearly two-thirds of the country elevators handling corn owned cleaners, while over half cleaned corn as part of normal operations. Small country elevators may choose not to purchase cleaners because of concerns for recouping the cost of investment. In addition, these who do own cleaners may choose not to clean sorghum because of a perceived limited demand for cleaner sorghum.

Inland Terminal Elevators

Reports from 45 inland terminal elevators, some of whom did not handle sorghum, indicated a total annual volume of 18.5 MB of all grains in 1990. Approximately 13 percent of their annual volume in 1990 was sorghum. Fourteen terminal elevators reported detailed characteristics on sorghum handled. These elevators handled an average of 20.4 MB of grain and soybeans during 1990, but 4 percent of their volume was sorghum. Approximately 93 percent of these elevators had cleaning equipment, and 21 percent indicated an ability to add cleaning capacity to existing facilities. Only one terminal elevator reported cleaning sorghum, and this facility on average cleaned 5 percent of the sorghum it handled, at a cost of 4 to 5 cents per bushel. Since few terminals reported cleaning cost information, the value of these data is limited.

Export Elevators

Export elevators occasionally clean sorghum, but only to meet contract specifications (not to avoid discounts). Unlike producers and country elevators, export elevators do not benefit from an improved storability of cleaner sorghum, since port facilities do not have long-term grain storage facilities. Only a few river and port elevators reported handling sorghum in the NGFA survey. To avoid disclosure of individual operations, detailed sorghum data for river and port elevators were not published in the Texas A&M University study (see Grant, Fuller, and Bello). Reports from 14 river and 13 port elevators (including those that did not handle sorghum) indicate an average total annual volume of 8.9 and 71.2 MB, respectively. Only 1 percent of river elevator volume in 1990 was sorghum, compared with 8.6 percent of the port elevator volume. About 85 percent of the port elevators had cleaning equipment, while 38 percent could add additional cleaning capacity to their existing facility.

Methodology

Portions of the FGIS-ERS research agreement were subcontracted to university researchers. A team at Texas A&M University was enlisted in late 1991 to conduct studies on the costs and benefits of cleaning sorghum in the United States. At the time, the FGIS had proposed (on April 2, 1991) a tightening of standards from a maximum of 8 percent BNFM to limits of 5 percent brokens and 2 percent foreign material.[9] Accordingly, the Texas A&M research team was asked to evaluate 5-percent BN, 2-percent FM as an alternative standard to the old 8 percent BNFM in assessing potential costs and benefits of cleaning sorghum. The team was also asked to explore a second alternative of 4-percent BN, 1-percent FM, although this standard had not been explicitly proposed in either the consensus report or by FGIS. Their work has resulted in three publications to date: Grant, Fuller, and Bello; Ziari, Fuller, Grant, and Sutaria; and Bello, Grant, and Fuller. Results and highlights of two of these studies are covered extensively in this and the next two sections.[10] Although further citations to these studies are infrequent, credit is explicitly acknowledged.

Costs and domestic benefits from cleaning were calculated for farms, country elevators, terminal elevators, and export elevators using surveys, economic engineering studies, and a cost-minimizing linear programming analysis. These calculations apply to the old grade limits for BNFM, the current grade limits for BNFM/FM, and the two "cleaner sorghum" BN-FM levels noted above. Throughout the remainder of this document, reference will be made to these four grading standards. These standards will be abbreviated as follows: (1) the "old" standard of 8-percent BNFM will be noted as such; (2) the "new" (June 1, 1993) standard of 7-percent BNFM, 2.5-percent FM (with FM as a subfactor of BNFM) will be abbreviated as 7/2.5; (3) the original proposed standard of 5-percent BN, 2-percent FM (with BN and FM as

---

[9]The 5 percent BN, 2 percent FM standard is a subset of the more lenient current standard.

[10]The Bello, Grant, and Fuller report is given only light coverage in this study. That study is concerned with how the added costs for cleaning sorghum at various locations in the marketing system are distributed.

separate factors) will be noted as 5-2; and (4) the stricter standard of 4-percent BN, 1-percent FM will be shortened to 4-1.[11]

Costing Methods for Economic Engineering Studies

In calculating costs for cleaning sorghum at various locations using economic engineering studies, the Texas A&M University team assumed elevators could install grain cleaning equipment in existing facilities and that they cleaned only that portion of the grain that did not meet the U.S. No. 2 grain standard. Since elevators handle multiple grains throughout the season, the cost of operating those facilities was allocated across all grains. Thus, the percentage of sorghum not meeting the U.S. No. 2 standard was applied to all grains, and cleaning costs for each elevator were calculated using the total grain volume handled times these percentages.

Machinery Requirements for Cleaning Sorghum at Various Locations

Machinery requirements for cleaning sorghum at various locations under alternative cleanliness standards can be found in appendix A. Information on the grain cleaners considered by the Texas A&M team was obtained from a 1991 survey of cleaning equipment manufacturers (Scherping, Cobia, Johnson and Wilson; Adam and Anderson). In assessing machinery requirements, a rotary screen cleaner was assumed for each location, allowing for comparison of the same technology across locations. The Texas A&M team assumed that the adopted cleaning technology could effectively remove the necessary BN and FM. Following an estimation technique used by Adam and Anderson, and Scherping et al., they estimated that a rotary screen cleaner would operate at 90 percent of its rated throughput when cleaning to meet the old U.S. No. 2 sorghum standard (8-percent BNFM); at 85 percent for the current No. 2 standard (7/2.5); at 80 percent for the FGIS proposed No. 2 standard (5-2); and at 70 percent for the more demanding standard (4-1).

For each of the locations in the marketing channel, an estimated 3.2 percent of the sorghum would need to be cleaned to meet the old U.S. No. 2 sorghum standard (8-percent BNFM); 10.8 percent would need to be cleaned to meet the current U.S. No. 2 standard (7/2.5); and 19.6 and 53.0 percent, respectively, would need to be cleaned to meet the original proposed (5-2) standard and the stricter (4-1) standard (see table 3). The required machinery was calculated as the least-cost combination of the three sizes of rotary screen cleaners needed to meet the quality standards. The calculations were made for the average elevator at each location in the marketing channel over two scenarios, cleaning sorghum during loadout or cleaning sorghum during storage. The loadout calculation determined the machinery needed to clean sorghum to each of the four standards and still maintain average sorghum flows. A similar storage calculation was done, but for only the strictest standard. Machinery purchase

---

[11]The inconsistency between the slash and the dash notation is intentional. The slash notation (7/2.5) refers to a set of standards where one factor (FM) is a subfactor of another (BNFM). The dash notation (5-2 and 4-1) refers to a very different set of standards where each factor (BN, FM) is evaluated separately.

prices were available, with installation costs assumed to be equal to the purchase price (Adam and Anderson).

Fixed and Variable Costs for Cleaning Sorghum at Various Locations

Economic engineering costs were estimated for cleaning sorghum to meet the four different standards for U.S. No. 2 grade at the four locations in the marketing system. Key assumptions employed in estimating fixed and variable costs for cleaning sorghum can be found in appendix B. Fixed costs are those that relate to the purchase and financing of additional cleaning equipment. Fixed cost items include depreciation, interest on investment, insurance, and taxes. Variable costs are those that relate to the operation of the cleaning equipment and to losses incurred as a result of the cleaning operation. These include wages and salaries, electricity, maintenance and repairs, handling loss, weight loss, and interest on working capital.

Using Linear Programming To Assess System Costs and Locations for Additional Cleaning within the Sorghum Industry

Investments in cleaning equipment and the fixed and variable costs associated with operation of the cleaning equipment make up the additional costs to the grain sorghum industry of implementing tighter standards. Per-bushel fixed and variable costs generated by the economic engineering approach (discussed above) were used by the Texas A&M team in a linear programming (LP) model to measure the increase in sorghum marketing system costs that would result with implementation of tighter standards. The LP model also computed the optimal locations within the market channel for additional cleaning capacity and identified regions where the additional investment in cleaning capacity would be most economical. Because onfarm cleaning costs were so high, that alternative was not considered. It was assumed that grain cleaning would be undertaken only at country elevators, terminal elevators, or port elevators.

When grain sorghum is cleaned to a tighter specification, two products are created: clean grain and screenings (foreign material, broken kernels, and whole-kernel sorghum separated in the cleaning process). Because clean grain is diminished in volume to some degree from its uncleaned state and because screenings are marketed back to cattle feeding areas, it was necessary to analyze the transportation system as a whole in assessing costs associated with varying cleanliness standards. That is, the estimated cost of cleaning sorghum to varying standards is spread across the entire sorghum marketing system. Thus, accurate per-bushel effects on the sorghum industry can be calculated.

A multiproduct, cost-minimizing quarterly spatial model of the grain sorghum sector was developed (Ziari, et al.).[12] The model depicted sorghum flows between country elevators, terminal elevators, port elevators, and demand locations, plus the associated cleaning activities at these grain-handling facilities. The multiproduct dimension allowed for sorghum that tested clean; sorghum that needed to be cleaned; and sorghum that had already been cleaned to meet the required level. Grain that failed to meet the standard was cleaned at country elevators or was shipped to other facilities in the channel for cleaning prior to shipment to demand locations. The spatial model linked 31 surplus production regions in the United States to 35 domestic sorghum-deficit regions and 13 foreign demand regions. Grain flows between surplus and deficit regions were based on patterns developed for the 1986-87 marketing year (Ziari, et al.).

The model was designed to optimally locate additional cleaning equipment at elevators in the various regions of the country. This objective was accomplished by minimizing the total annual costs of transportation, handling, storage, cleaning, and the disposal of screenings subject to a set of capacity constraints and supply-demand balance equations. Four modes of transportation (rail, truck, barge, and ship) were considered (Ziari, et al.). The cost of grain shipment included handling and transportation costs. Storage costs were included for storing grain at country elevator and terminal locations. Annual cleaning costs included the variable cleaning costs and fixed costs incurred if any elevator locations increased their cleaning capacity. Finally, the costs of handling and transporting screenings were included.

The lower fixed cost for larger operations (obtained from the economic engineering studies) suggests that terminal and port elevators may be the optimal cleaning location in the market channel. However, the least-cost location in the market channel is also affected by the proximity of the cleaning location to the demand regions for grain and for screenings. Grain sorghum screenings are palatable and nutritionally valuable ingredients for fattening cattle (Ash and Lin). Cattle feeding areas are more often near country elevators or terminals in the supply regions. Consequently, the costs associated with the transportation of screenings would be less when cleaning at the country elevators or terminals compared with cleaning at port. In addition, revenues from screenings sales are typically greater at country elevators than at terminal or port elevators. Thus, the optimal cleaning location in the market channel is determined by tradeoffs between the economies of size in the grain cleaning activity and the transportation costs associated with the marketing of grain and screenings.

Calculating Benefits of Cleaner Sorghum

Calculations of the benefits of cleaner sorghum centered on four items: (1) revenue from selling grain sorghum, (2) revenue from selling sorghum screenings, (3) savings in storage costs, and (4) savings in transportation and handling costs.

---

[12]The model included 7 terminal locations (Amarillo, Ft. Worth, Kansas City, Wichita, Omaha, St. Louis, and Memphis); 18 barge-loading sites (on the Missouri, Arkansas, and middle and lower Mississippi Rivers); and 5 port areas (Mobile, New Orleans, Galveston-Corpus Christi-Brownsville, Portland, and Seattle).

Grain sorghum prices are readily available. The national average monthly sorghum price during 1988-92 ranged from $1.54 per bushel in January 1988 to $2.49 per bushel in July 1990 (USDA, NASS, 1993). The average annual sorghum price in the three largest sorghum producing States (Kansas, Texas, and Nebraska) ranged from $1.87 per bushel in 1992 to $2.31 in 1988 (USDA, NASS, 1992, 1993). In our analysis, we use three levels of the sorghum price ($1.70, $2.00, and $2.30 per bushel) to assess the net benefits of alternative grade standards. Only the results for the $2 price are presented in the text. Further results are presented in appendix D. The screenings price was set at $40 per ton ($1.12 per 56-pound bushel) in the text and at $34, $40, and $46 per ton (56 percent of the sorghum price) in appendix D.[13]

The latter two benefit items are savings that result from a smaller amount of grain sorghum remaining after screenings have been removed. There is a decrease in the total cost to store the smaller volume of clean grain, and there is a decrease in the total transportation cost to ship the smaller volume of clean grain through the remainder of the marketing system. Details on these calculations can be found in Ziari, et al.

Determinants of Costs and Benefits of Cleaning

Producers' and handlers' decisions to clean sorghum are based on a comparison of the benefits and costs of lowering the BN or FM levels. The factors affecting costs and benefits of cleaning include:

Costs	Benefits
(1) the cost of operating cleaners	(1) improved storability
(2) cleaning capacity and efficiency of cleaners	(2) reductions in discounts or increases in premiums
(3) weight loss	(3) decreased storage and transportation costs of clean grain
(4) marketing and disposal costs of screenings	(4) revenue generated from screenings sales
(5) the beginning and ending BNFM levels	(5) increases in import demand for U.S. sorghum

Determinants of the Costs of Cleaning Sorghum

Although the determinants of costs of cleaning sorghum are separated into distinct categories, they are interrelated. For example, weight loss increases as the difference between the beginning and ending BNFM level widens. Also, higher capacity machines typically result in higher fixed costs (capital costs) and lower average variable costs (operating costs).

---

[13]Our reasoning for these values is set forth in the next section.

Cost of Operating Cleaners

Costs of operating a grain cleaner include fixed and variable costs. Fixed costs are ownership costs, primarily depreciation, interest expense, taxes, and insurance. These costs remain the same regardless of intensity of use. Because fixed costs are invariant with use, intensity of use is the major determinant of per-bushel fixed costs and of the fixed cost percentage in the total cost of operating a cleaner. Per-bushel fixed costs can be reduced if the cleaner is also used to clean other grains.

The variable costs of operating a cleaner are the costs that are incurred only when the cleaner is in operation. These costs include labor, energy use, and repair and maintenance. Labor costs dominate these variable operating costs (see appendix C). New elevator construction and existing elevator modification typically take labor costs into account in attempting to automate as much of the grain handling as possible. Both labor costs and energy use increase when the grain is cleaned during storage and provision must be made for transferring grain to the cleaning location and back to the storage bins.

Capacity and Efficiency of Cleaners

Capacity and efficiency of a grain cleaner are important determinants of cleaning costs. A tightening of grade standards will typically require increased cleaning capacity as blending to meet a given standard becomes more difficult. Larger machines have larger capacities and are typically able to operate more efficiently (lower variable costs), but they also require a larger initial investment (higher fixed costs). Larger capacity machines are needed at terminal and port elevators where throughput is higher. Machines with small unit capacities are best suited for farms or elevators that have or require small quantities of sorghum cleaning.

Cleaning capacity is inversely related to cleaning efficiency. For a given machine, the lower the cleaning efficiency (i.e., smaller the amount of BNFM removed), the higher will be the capacity. The manufacturer's rated throughput is usually quoted at a very low efficiency. Thus, the most common method for increasing a machine's cleaning efficiency is to lower the throughput rate. Effective cleaning capacity diminishes as the proportion of material removed from the grain (screenings) increases.

Weight Loss

Higher levels of cleaning efficiency result in greater amounts of whole sorghum being removed. Total revenue is thus decreased because the good sorghum included with BN and FM in the screenings is sold at the lower screenings price instead of the higher sorghum price. This loss of revenue is known as weight loss (or cleaning loss). Weight loss is often the largest cost component associated with additional cleaning, as we will see in the next section. Although cleaning during storage requires additional handling (and increased costs as a result thereof), there is no difference in actual weight loss levels between cleaning in storage and cleaning during loadout when the equipment is run at the same speed for each process.

However, as a percentage of the variable costs of cleaning, weight loss is greater when sorghum is cleaned during loadout, primarily due to the decrease in labor costs.

Weight loss varies across the various types of cleaners. Weight loss is typically highest with aspiration cleaners and lowest for screen cleaners. Although settings can be adjusted on most mechanical cleaners to diminish this weight loss, lower weight loss typically requires a lower throughput rate, which is also costly.

Marketing and Disposal Costs of Screenings

Most sorghum screenings are sold as components for byproduct feeds to offset the value of the weight loss. However, there are some costs incurred in marketing screenings. Storage and transport costs for sorghum screenings are not appreciably different from those for sorghum grain. Hence, these items only become cost factors as distance to feeding centers increases or as market conditions for screenings necessitate storage instead of immediate shipment. Because most feeders and feed manufacturers are located near grain production areas, additional transportation costs for shipping screenings to these facilities are lowest at the farm level. Many farmers feed screenings to their own livestock. Export elevators incur the highest per-unit transport costs because of the greater transportation distances.

Producers would incur little additional screenings storage costs because they typically can feed screenings to their own livestock soon after cleaning. Elevators, however, would incur additional costs for storing screenings, since it is not cost-efficient to transport screenings after each cleaning. Storage of screenings is an unprofitable activity (screenings typically lose much of their nutritive value after about 1 month), and elevator operators prefer to devote their available facilities to higher valued grain. Terminal elevators are in the best position for storing screenings because of their larger capacity. Country elevators are at a disadvantage because they generally have smaller storage capacity, while port elevators are more focused on throughput than on storage.

If the distance to feeding centers is long, disposing of screenings can increase the costs of cleaning sorghum. However, nearly all terminal and port elevators can sell their screenings as byproduct feeds, and very few producers and country elevators are without some sales outlets for their screenings. Hence, the percentage of market participants facing disposal costs is too small to include screenings disposal costs in the cost analysis.

Beginning and Ending BNFM Levels

Beginning and ending BNFM levels are important factors in determining costs of cleaning. As stricter cleanliness standards are enacted, cleaning machines must run at lower throughput rates, increasing cleaning time and per-bushel costs. This is particularly true when the difference between old-standard and new-standard BNFM levels is large. In addition, cleaning also takes more time when beginning and ending BNFM levels are both at very low

levels. It is more difficult to achieve a 1-percentage-point BNFM reduction in sorghum from an initially low BNFM level than from an initially high BNFM level.[14]

Determinants of the Benefits of Cleaning

Decreased storage and transportation costs of clean grain and the revenue generated from screenings sales are the major benefits from cleaning sorghum. Potential safety and health benefits, such as insurance savings from reduced dust levels, are not addressed in this report.

<u>Improved Storability</u>

Cleaning reduces potential sorghum loss during storage and extends its safe storage life by improving airflow and by reducing power requirements, shrinkage, mold growth, and insect damage. Because sorghum is harvested at a much lower moisture content than corn and is thus much less susceptible to the development of storage mold, improved storability is not as big a benefit component to sorghum producers and handlers as is the case for corn. However, the longer the expected length of storage, the greater would be the benefit of cleaning sorghum prior to, or during, storage. Country and terminal elevators stand to benefit most from the improved storability of clean sorghum, because they assemble and store a large volume of sorghum from producers. Export elevators would derive little benefit from enhanced storability because sorghum is stored only for short periods at these facilities.

<u>Reduction in Discounts and Increases in Premiums</u>

Discounts and premiums are not a major issue in U.S. sorghum markets. U.S. grain markets generally do not offer premiums for clean grain. Premiums for clean sorghum are especially rare. Discounts for sorghum are also not common, except for reductions in paid weight due to excessive dockage levels. Naturally, if BN or FM levels are too high, sorghum may test out to a lower quality grade, resulting in a lower price received per bushel.

<u>Decreased Storage and Transportation Costs of Clean Grain</u>

Sorghum storage and transportation costs decrease with additional cleaning due to the smaller amount of clean sorghum remaining after screenings have been removed. Both the total cost to store the smaller volume of clean grain and the total transportation cost to ship the smaller volume of clean grain through the remainder of the marketing system are lower. The higher the cleanliness level, the greater will be the amount of screenings removed and the larger will be the storage and transportation savings. These savings provide only partial compensation for the costs associated with weight loss.

---

[14]However, if BNFM is low initially, the sorghum probably does not need to be cleaned.

Screenings Sales

Revenue from the sale of screenings will partially offset the value of weight loss that occurs during the cleaning process. The price of screenings is determined by the price of sorghum and by supply and demand in the market for grain screenings. Corn dominates in the grain screenings market. Although there is no well-defined market for sorghum screenings, their value is probably 50 to 60 percent of the sorghum price. Hill and others found that corn screenings generally run 70 to 80 percent of the value of corn. Even with an enhanced supply as a result of stricter cleanliness standards, their estimate was that corn screenings would be no lower than 60 percent of the corn price. Thus, with a corn price of $2.20 per bushel, corn screenings might range from $1.32 to $1.76 per bushel. However, corn screenings contain considerably more broken corn content than is the case for broken sorghum in sorghum screenings. Accordingly, we would not expect sorghum screenings to be priced so high relative to sorghum grain as are corn screenings to corn.

Three other pieces of evidence corroborate the sorghum screenings-to-grain price ratio suggested above. First, "ground grain screenings" are priced in *Feedstuffs* magazine (September 20, 1993) at $61 to $64 per ton, or $1.71 to $1.79 per 56-pound bushel. However, ground grain screenings would be expected to test out at less than 56 pounds per bushel. Using the $64 quote results in a screenings price of $0.96 for a 30-pound bushel, $1.28 for a 40-pound bushel, and $1.79 for a 56-pound bushel. Second, Brethour calculated a sorghum liftings (screenings) price of $1.53/cwt, or $0.43 per 28-pound bushel ($0.86 per 56-pound bushel) in his study of the nutritional value of wheat and milo liftings in cattle feed rations. Finally, Grant et al. used a sorghum screenings value of $2 per hundredweight ($0.60 for a 30-pound bushel, $0.80 for a 40-pound bushel, and $1.12 per 56-pound bushel) in their economic engineering studies. As noted earlier, sorghum prices used in this study ranged from $1.70 to $2.30 per bushel. Thus, the sorghum screenings price in the text of $40 per ton ($1.12 per 56-pound bushel) varies from approximately one-half to two-thirds of the sorghum price, while screenings set at 56 percent of the sorghum grain price results in a screenings prices of $0.95, $1.12, and $1.29 per 56-pound bushel in appendix D.

Increases in Import Demand for U.S. Sorghum

The final potential benefit accruing to sorghum producers and merchants is an increase in export revenue due to either higher prices or enhanced import demand associated with cleaner U.S. sorghum. Gains will be realized if (1) current import demand for sorghum is inelastic, (2) an additional import demand for cleaner sorghum exists, or (3) U.S. merchants can capture greater market shares in existing markets. Because a certain amount of whole sorghum is removed during the cleaning process, all other things being equal, market prices for sorghum would rise somewhat with additional cleaning. If import demand were inelastic, this increase in the sorghum market price would be offset by a smaller percentage decrease in exports, resulting in additional revenues. This outcome is more likely if cleaning costs per bushel of sorghum are relatively small and the loss of whole sorghum is marginal. Also, because sorghum constitutes a relatively small share of world trade in feed grains, it is unlikely that import demand for sorghum is inelastic.

There is also the potential that cleaner sorghum will command a higher price in world markets or that there is some latent demand for cleaner sorghum. This outcome is unlikely, however, in that U.S. No. 2 sorghum is clearly the dominant export grade. Importers who have had U.S. No. 1 sorghum available to them in the past have seldom chosen to purchase the higher grade, possibly because a large percentage of the sorghum that goes out under U.S. No. 2 contract actually meets U.S. No. 1 standards. The large majority of U.S. sorghum exports are used by importers for feeding livestock, and cleanliness is less critical when grain sorghum is used for feed. Broken kernels are only slightly less nutritious than whole kernel sorghum and constitute roughly 70 percent of the BNFM level in export sorghum. Thus, uncleaned sorghum, with FM-plus-dockage levels of only 2 percent, remains a nutritionally sound feed ingredient.

It is also unlikely that U.S. merchants can make inroads into new markets. Over the last 4 marketing years, only 20 countries imported U.S. sorghum, yet the U.S. market share of world sorghum exports was nearly 80 percent. During this time period, Mexico and Japan have dominated world sorghum imports, with 90 percent of U.S. sorghum exports and two-thirds of the entire world's sorghum exports going to these two countries. U.S. sorghum exports constitute nearly 100 percent of Mexico's import market and nearly 60 percent of Japan's sorghum imports. Presumably, U.S. exporters could capture a larger share of Japan's import market, largely at the expense of Argentina. U.S. gains in Mexico, however, are not possible without absolute market growth. In fact, it may be difficult to even maintain current levels of sorghum exports to Mexico in light of the potential for growth in U.S. corn exports to Mexico under the North American Free Trade Agreement. Other potential import markets for sorghum where the U.S. market share has historically been small include Taiwan, South Korea, and Turkey. Naturally, sorghum exports could increase to any country where sorghum could substitute for imported or locally produced feed grains. Corn provides the major competition, and gains of this nature are dependent on corn market conditions, especially changes in the corn-to-sorghum price ratio.

Costs and Benefits of Cleaning Sorghum

This section presents estimates of the additional costs and benefits of cleaning U.S. No. 2 sorghum to stricter standards. These estimates were obtained by combining assumed levels of sorghum grain and screenings prices with the cost estimates and sorghum grain flow results from the linear programming (LP) model described earlier. Per-bushel fixed and variable costs generated by the economic engineering approach were used as inputs into the LP model. These costs are analyzed in appendix C. The LP model calculates the total system cost of cleaning sorghum to alternative standards, computes the optimal locations within the market channel for additional cleaning capacity, and identifies regions where the additional investment in cleaning capacity would be most economical. Only summary results are presented in the text. More detailed results can be found in appendix D.

The analysis focuses only on U.S. No. 2 sorghum. It was assumed that buyers would continue to purchase U.S. No. 2 sorghum and not drop to a lower grade. The option of

cleaning sorghum onfarm was excluded from the model. Additional costs and benefits are presented in table 4 for the case where all marketed sorghum is required to meet U.S. No. 2 grade and in table 5 when only export sorghum must meet U.S. No. 2 grade. The implicit assumption in the table 5 scenario is perfect knowledge on the part of sorghum merchandisers as to the final destination of all export sorghum. Although this premise is unlikely, the estimates do serve as a point of reference. The model results for cleaning locations and the necessary investment in additional cleaning equipment are shown in tables 6 and 7.

Additional Costs and Benefits of the Recent Change in Standards

Estimates of the additional costs and benefits of cleaning sorghum to meet the current standard (7-percent BNFM, 2.5-percent FM) over the old standard (8-percent BNFM) are presented in the first column of tables 4 and 5. The LP results indicate that existing cleaning capacity was sufficient to meet the new standard so that no investments in cleaning equipment were necessary (Ziari et al.). If all marketed sorghum is required to meet U.S. No. 2 grade limits, the additional system cost of the current standard over the old standard is estimated at $0.61 million (table 4). If only export sorghum must pass grade, the additional cost decreases almost 60 percent, to $0.26 million (table 5). The net costs per bushel of marketed sorghum are quite small, at 0.16 and 0.07 cent, respectively, for all marketed sorghum passing grade and for only export sorghum passing grade. The costs per bushel cleaned are somewhat larger, at 1.52 and 0.66 cents, again respectively.

In both cases, over 80 percent of the additional cost is the value of weight loss. The largest benefit item is the revenue generated from the sale of sorghum screenings, although transportation savings also constitute a substantial portion of total benefits. The negative savings in storage costs when all sorghum must meet grade are the result of cleaning taking place year-round at country elevators in lieu of purchasing additional cleaning equipment (table 4). When sorghum is cleaned for only foreign markets, the amount of sorghum requiring cleaning is substantially lower, sorghum is cleaned earlier in the marketing year, and storage costs reflect a net savings (table 5).

Under the old standard, the solution from the LP model has cleaning taking place almost exclusively at country elevators in both of the cleaning requirement scenarios (tables 6 and 7).[15] Country elevators still dominate under the current standard, with just over 10 percent of the cleaning shifting to terminal elevators. Cleaning costs per bushel are lower at terminal and port elevators, but the proximity of country elevators to feeding centers provides a cost advantage to the country elevators in disposing of screenings. No additional investment in cleaning capacity is needed in either scenario under either the current or the old standard.

---

[15]When the old standard was in place, most of the sorghum cleaning took place at country elevators.

Table 4--Benefit-cost analysis of additional cleaning necessary to bring all marketed sorghum to U.S. No. 2 standard

Benefit or cost item	7% BNFM[1] 2.5% FM	5% BN[2] 2% FM
	Million bushels	
Clean sorghum marketed	389.36	388.36
Screenings generated	1.20	2.20
	$1,000	
Additional cost	$2,309	$2,910
Weight loss	1,860	2,000
Cleaning cost	312	746
Marketing screenings	137	164
Additional benefits	$1,701	$2,140
Screenings sales	1,042	1,120
Storage savings	(5)	72
Transportation savings	664	948
Additional net cost	$608	$770

[1]Additional costs and benefits of cleaning to 7% BNFM, 2.5% FM in excess of cleaning necessary to meet 8% BNFM.
[2]Additional costs and benefits of cleaning to meet new standard in excess of cleaning necessary to meet 7% BNFM, 2.5% FM.

Table 5--Benefit-cost analysis of additional cleaning necessary to bring only export sorghum to U.S. No. 2 standard

Benefit or cost item	7% BNFM[1] 2.5% FM	5% BN[2] 2% FM
	Million bushels	
Clean sorghum marketed	389.71	389.08
Screenings generated	0.85	1.48
	$1,000	
Additional cost	$1,568	$1,816
Weight loss	1,260	1,260
Cleaning cost	208	463
Marketing screenings	100	93
Additional benefits	$1,304	$1,331
Screenings sales	706	706
Storage savings	9	44
Transportation savings	589	582
Additional net cost	$264	$484

[1,2]See footnotes, table 4.

Table 6--Cleaning locations and additional investment when all marketed sorghum must meet U.S. No. 2 grade

Item	8% BNFM	7% BNFM 2.5% FM	5% BN 2% FM
		Million bushels	
Total sorghum handled	390.56	390.56	390.56
Total cleaned	12.81	39.93	71.00
Country elevator	12.25	34.99	50.64
Terminal elevator	.56	4.43	20.13
Port elevator	0	.51	.23
Screenings generated	.27	1.20	2.20
		$1,000	
Cleaner investment:			
Country elevator	0	0	2,496
Terminal elevator	0	0	661
Total	0	0	3,157

Table 7--Cleaning locations and additional investment when only export sorghum must meet U.S. No. 2 grade

Item	8% BNFM	7% BNFM 2.5% FM	5% BN 2% FM
		Million bushels	
Total sorghum handled	390.56	390.56	390.56
Total cleaned	10.33	28.19	47.67
Country elevator	10.12	25.27	35.90
Terminal elevator	.21	2.83	11.77
Port elevator	0	.09	0
Screenings generated	.22	.85	1.48
		$1,000	
Cleaner investment:			
Country elevator	0	0	1,248
Terminal elevator	0	0	661
Total	0	0	1,909

Additional Costs and Benefits of Stricter Cleaning Standards

The second column of tables 4 and 5 presents estimates of the additional costs and benefits of moving to an alternative cleanliness standards (5-percent BN, 2-percent FM) which is more stringent than the current standard. Although the 5-2 standard is actually one of the boundary sets of the current standard (since its combined BNFM level is the current maximum, 7 percent), it still is a tighter standard because of the separate restrictions on BN and FM levels.

As standards become tighter, the clean grain volume decreases while the weight loss and screenings volume increase. Moving from the current standard to the 5-2 standard results in a total additional system cost (net of revenues) of $0.77 million when all marketed sorghum must pass U.S. No. 2 grade limits (table 4) and $0.48 million when only export sorghum must pass grade (table 5).[16] On a per-marketed-bushel basis, the cost is 0.2 and 0.12 cent, respectively. The additional cost per-bushel cleaned is approximately 5 times greater, at 1.08 and 0.68 cents per bushel, again respectively. In contrast with the move from the old standard to the current standard, weight loss accounts for less than 70 percent of the additional costs incurred in moving from 7/2.5 to 5-2. Cleaning costs, however, nearly double in component size, now accounting for nearly 26 percent of additional system costs. This increase is the result of additional investment in cleaning equipment necessary with the tighter standard (tables 6 and 7).

Although country elevators still dominate as the preferred cleaning locations under the 5-2 standard, a greater percentage of the cleaning now is undertaken at terminal elevators (tables 6 and 7). If all marketed sorghum had to pass U.S. No. 2 grade limits, 28 percent of the cleaning would take place at terminal elevators, while 25 percent would be cleaned at terminal elevators if only export sorghum had to pass grade. Port elevators still would not be heavily involved in cleaning sorghum. Additional cleaning capacity would be needed, $3.2 million when all marketed sorghum must pass grade (table 6) and $1.9 million when only export sorghum pass grade (table 7). The bulk of the investment occurs at country elevators. The cleaner investment costs listed in the tables are full purchase price figures (including installation) that are depreciated over a 20-year horizon in the LP model. When these costs are amortized, they become a part of the annualized additional cleaning costs in tables 4 and 5. Thus, there is no direct comparison between these cleaning costs and the investment costs in tables 6 and 7.

Changes in Import Demand for U.S. Sorghum

Much of the focus in the wheat, corn, and soybeans grain quality studies was on the potential benefits afforded U.S. grain producers and merchants if the U.S. agricultural sector were to

---

[16]Cost and revenue calculations for moving from the current standard to the 4-1 standard are discussed in appendix D. The net additional cost of moving to the 4-1 standard is $5 million more than the net additional cost of moving to the 5-2 standard when all marketed sorghum must pass U.S. No. 2 and $2 million more when only export sorghum must pass grade (app. table D-1).

offer cleaner export grain. In studying these three commodities, analysts traveled extensively to importing countries to assess their demand for U.S. grain and to survey their concerns about the quality of U.S. grain. Data and information gathered from these trips were then analyzed to examine the potential gains available from cleaner U.S. export grain. No such travel was undertaken to assess sorghum markets. In the absence of these primary data, analysis of the effect of cleaner U.S. sorghum on foreign demand must rely on the study results of corn cleaning and other secondary evidence.[17]

A small amount of evidence supports the premise that the U.S. sorghum industry stands to gain substantially from cleaner U.S. sorghum in export markets. The first is that, for the most realistic alternative standard being considered, cleaning costs per bushel of sorghum are relatively low and the amount of sorghum removed during the cleaning process is marginal (see above). Thus, any adverse market effects from additional cleaning should be relatively small. Second, the export demand for sorghum may be relatively inelastic. Bello et al. estimated an export demand price elasticity for sorghum of -0.43 to -0.68, again suggesting that adverse market effects from additional cleaning would be relatively small. Thus, the slightly higher market price together with the inelastic demand could result in additional export revenues for sorghum merchants.

On balance, the secondary evidence weighs against major benefits accruing to the U.S. sorghum industry from cleaner export sorghum. As discussed in the previous section, it seems unlikely that a latent demand for cleaner sorghum exists; that cleaner sorghum will command a higher price in world markets; or that U.S. merchants can capture greater market shares of existing markets. More importantly, however, sorghum markets are dominated by corn, and corn importers seem largely unmoved by prospects for cleaner U.S. corn. Results from a recent grain quality report on corn (Mercier) likely have direct application to sorghum. This study found that importers expressed little interest in either paying more for cleaner U.S. corn or importing greater quantities of cleaner corn. Quality was ranked as high as second (behind price and related factors) in import decisionmaking in only four of eight study countries.

In markets in which quality was considered relatively important, major concerns were BCFM (the corn equivalent to sorghum's BNFM) and storage quality. However, the BCFM concern in corn is more a problem for the grain dust created than for intrinsic nutritional factors. Because of its larger kernel size and the high-temperature drying that corn undergoes due to its higher moisture content at harvest, corn is much more susceptible to breakage than sorghum. Another major issue with storage quality is moisture levels, especially in humid climates. Again, because sorghum is drier at harvest and retains its integrity better through storage and handling, storage loss due to brokens and moisture levels is less a problem with sorghum than with corn. Quality was more important to corn processors, but many of these were already purchasing higher grade corn.

---

[17]See the ERS international corn cleaning report for more discussion on the coarse grain market (Mercier).

Policy Implications

There is no economic basis for additional cleaning of grain sorghum destined for export in the United States. Cleaning all marketed sorghum beyond the current U.S. No. 2 standard of 7-percent BNFM, 2.5-percent FM (with FM as a sub-factor) to a tighter standard of 5-percent BN, 2-percent FM (with BN and FM as separate factors) had a shortrun net cost to the U.S. sorghum industry of $0.8 million per year. Applying an even tighter standard of 4-percent BN, 1-percent FM had a shortrun net cost of $5.8 million per year. No appreciable international benefits from additional cleaning in terms of premiums or increases in the volume of U.S. sorghum exports were identified in this study.

It is not economical to do additional sorghum cleaning at any point in the marketing channel. However, if cleaning were necessary, least-cost solutions consistently dictated that the bulk of the cleaning take place at country elevators, due to the proximity of feeding centers. Because cleaning costs at country elevators would decrease if fixed costs were lowered substantially, research efforts should focus on cleaning technology, particularly the development of smaller, more efficient machines targeted to the lower capacity of country elevators.

Cleaning sorghum to standards beyond the current levels would require more incentives than currently exist in the marketplace. These incentives must come from domestic and foreign buyers, in terms of premiums or increased demand. However, because sorghum is primarily a feed grain, end users are not likely to be willing to pay higher prices for cleaner sorghum. The substitutability between sorghum and other feed ingredients, especially corn, makes premiums for clean sorghum even less likely.

Policy Options

This section extends the scope of the study beyond the costs and benefits of cleaning sorghum to an exploration of alternative policy options for improving the cleanliness of U.S. sorghum and for better meeting the quality needs of foreign buyers. It is important to note that policy options included in this section must be further evaluated in terms of their cost-effectiveness before any serious consideration be given to them.

The policy options considered in this section are limited to changes in U.S. grades and standards for sorghum. As noted above (and excepting the likely gains from improved blending practices), tighter standards would result in lower percentages of samples achieving a certain grade level. Because lower quality grades sell at a discount to higher quality grades, producers and merchants must either deliver cleaner grain or risk accepting penalties. That is, revised production practices, additional cleaning and/or more constrained blending practices would most likely become standard practices for U.S. produced sorghum under any of these alternative scenarios. A number of alternatives are available to FGIS as it considers further modifications in sorghum grain quality standards. Some of the more prominent options include:

1. Evaluating BN and FM as separate factors,

2. Reductions in maximum BNFM or FM levels (while maintaining FM as an explicit subfactor), and
3. Changing dockage reporting methods.

Each of these options is discussed in turn below. For the remainder of this section we use failure rates of export samples (the percentage of export samples that fail to pass U.S. No. 2 grade) to assess the effect of changes in U.S. grades and standards for sorghum.

Evaluating BN and FM as Separate Factors

Under the current FGIS grading standards, FM is calculated as a subfactor of BNFM. In its original proposed rules change (April 1991), FGIS had recommended that BN and FM be graded as separate factors. A number of BN-FM combinations are possible subsets of the current 7/2.5 standard, including 6-percent BN, 1-percent FM and 5-percent BN, 2-percent FM as boundary sets. When these boundary sets are calculated as separate BN-FM grade factor maximums (instead of as a combined BNFM/FM measure), their rejection rates are much higher than the 7/2.5 subfactor standard. This is shown in table 8, where the numbers on the diagonal that run from 6-percent BN, 1-percent FM to 4.5-percent BN, 2.5-percent FM represent rejection rates for possible BN-FM subsets of 7/2.5 graded out as separate factors. The smallest of these rejection rates, 19.9 percent for 4.5-percent BN, 2.5-percent FM, is more than double the 8.3 percent failure rate for the 7/2.5 standard.[18] The 22.2-percent rejection rate for the 5-2 standard applied to export samples is slightly higher than the 19.6-percent failure rate applied to domestic samples that was used in the cost-benefit analysis of alternative standards. As the FM standard is tightened further (down and to the left along this diagonal), the rejection rates become prohibitive. Finally, restricting either BN or FM further from a boundary set combination (moving either rightward or downward off the diagonal) increases the rejection rates substantially.

The argument for separating broken sorghum and foreign material is that foreign material differs dramatically in chemical composition and physical properties from broken sorghum. Although FGIS export inspections have recorded BN and FM separately since 1987, foreign buyers do not receive this information. Separating the BNFM grade standard factor into two

[18]Rough estimates of the additional net cost of cleaning export sorghum beyond the 7-percent BNFM, 2.5-percent FM standard can be inferred by inserting rejection rates into the following table and interpolating. The estimates listed assume 2 cents per bushel cleaning costs at export elevators, a $2-per-bushel price of sorghum, and a $0.76-per-bushel price of sorghum screenings ($1.12 per bushel less $0.36 per bushel transportation and handling costs to feeding centers). Using these assumptions, the cost of cleaning 8.3 percent of export sorghum to meet the current 7/2.5 standard is $0.92 million.

			Percent		
Rejection rate	10	20	30	40	50
			Million $		
Cost of cleaning	1.14	2.65	4.26	6.04	8.01
Cost in excess of 7/2.5	.22	1.73	3.33	5.12	7.09

Table 8--Rejection rates for BN and FM as separate factors

FM level	BN level 6.0	5.5	5.0	4.5	4.0
			Percent		
2.5	5.8	7.4	11.2	19.9	37.7
2.0	17.2	18.7	22.2	29.6	44.5
1.5	47.7	48.7	50.9	55.0	62.7
1.0	82.4	82.6	82.9	83.5	85.1

components would allow buyers to differentiate between the two components, and this distinction may be of interest to some foreign buyers. For the most part, feed manufacturers do not like FM in the sorghum they buy, but are fairly tolerant of broken sorghum.

Separating BNFM into two grade-determining factors will not, by itself, induce significant changes in management practices to lower BNFM. For the most part, cleaner sorghum in the market channel would be generated only if the separation of BN and FM includes a reduction in the combined allowable limits. There are some cases, however, where a separate factors standard would require additional cleaning while a subfactors designation would not. For example, sorghum that tested out as 5.2-percent BN, 1.5-percent FM would grade out as U.S. No. 2 under the current 7/2.5 regime but would require additional cleaning to remove BN in order to meet U.S. No. 2 under a 5-2 standard. Although separating BNFM into the two factors would not increase inspection costs, the separate factors requirement would be costly for producers whose sorghum fails to achieve the higher grade because of the new designation. The U.S. sorghum industry would incur a net cost of $0.8 million under the 5-percent BN, 2-percent FM standard, and $5.8 million under the 4-percent BN, 1-percent FM standard. Thus, separating the BNFM grade factor into two components without any change in grade limits would generate additional costs with little benefit and only minor improvement in overall sorghum cleanliness (see Hill et al., 1993).

Reductions in Maximum BNFM or FM Levels

The current 7-percent BNFM, 2.5-percent FM cleanliness standard for U.S. No. 2 sorghum was a two-fold tightening of the 8-percent BNFM standard: a 1-percentage-point decrease in the maximum BNFM level and the institution of a maximum FM level. It is appropriate to consider the potential effects of a further tightening of either of these factors. Reducing the maximum allowable levels of BNFM or FM is preferred by a number of sorghum producers and merchants over evaluating BN and FM as separate factors. The major argument for subfactors over split factors is the flexibility that is retained in sorghum merchandising. Subfactor grading criteria allow exporters and intermediate handlers many more permissable

factor combinations than do separate factors criteria. There are many combinations of tighter BNFM/FM standards that would result in lower rejection rates than their "equivalent" separate factors failure rates. We saw above the higher rejection rates for the boundary sets of 7/2.5 BNFM/FM when they were evaluated as separate factors (see table 8). Finally, there are a number of market participants, both sellers and end-users, whose primary concern is achieving lower FM levels in sorghum. Sellers see high allowances on foreign material as damaging to their ability to market clean sorghum, while end-users desire less FM variability in the sorghum they receive.

Only one sorghum export sample (of 2,022 graded) exceeded the 8-percent BNFM standard between 1988 and 1992. If the 7/2.5 standard were applied to these 1988-92 sorghum export samples (without the benefit of blending), 8.3 percent would fail.[19] Rejection rates for this standard and for tighter BNFM and FM standards are presented in table 9. Rejection rates would more than double (to 18.7 percent) if FM were tightened by 0.5 percentage point, and more than triple (to 26.1 percent) if the maximum BNFM level were lowered by 1 percentage point, with additional costs to the U.S. sorghum industry associated with these increased rejection rates. Tightening standards on both factors (6-percent BNFM, 2-percent FM) results in a near quadrupling of the 7/2.5 rejection rate, to 31.5 percent. From the table, it seems clear that some tightening of these standards is possible, but that excessive tightening could be very costly.

Lowering the factor maximum of either BNFM or FM would likely induce additional sorghum cleaning, because producers and merchants would want to avoid the lower-grade penalties. However, not as many elevators have disc/cylinder cleaners for removing FM as have screen cleaners for removing BN. Whether cleaner export sorghum would command a higher price or enhance demand is uncertain. However, this result can be obtained with only positive net costs of additional cleaning, as shown earlier. Moreover, there is no guarantee that lowering the BNFM or FM grade limits will improve the cleanliness of U.S. export sorghum, since foreign buyers could shift their purchases to higher numerical grades. This option does not force buyers to choose cleaner sorghum, and it will not dictate market response (Hill, Bender, and Beachy). Finally, because foreign buyers can already purchase cleaner sorghum (at higher prices) under the current U.S. grades and standards, lowering BNFM or FM grade limits may be unproductive.

Changing Dockage Reporting Methods

Dockage is measured and recorded by FGIS inspectors in tenths of a percent, but reported officially in truncated whole percents. The seller is subject to penalty (a percentage-weight reduction) when the dockage level is 1 percent or more. In its April 1991 proposed rules change, FGIS had recommended that dockage be reported in tenths of a percent instead of the

---

[19]We saw earlier that the current standard applied to 1987-91 domestic sorghum samples would have resulted in a 10.8-percent failure rate compared with a 3.2-percent failure rate for the 8-percent BNFM standard.

Table 9--Rejection rates for tighter BNFM and FM levels

FM level	BNFM level 7.0	6.0	5.0	4.0
	Percent			
2.5	8.3	26.1	63.9	91.1
2.0	18.7	31.5	64.4	91.1
1.5	48.1	53.2	68.9	91.4
1.0	82.4	82.9	84.6	93.2

current practice of rounding down to the whole percent. This proposal met with a good deal of opposition from the sorghum industry, especially grain handlers and merchants, and FGIS elected to investigate alternative options regarding dockage prior to possible action at a later date. One of the suggested options was to delete the term "dockage" altogether and combine material currently defined as dockage with FM in the grading standards. Accordingly, we now investigate the two options discussed here, reporting dockage in tenths of a percent and including dockage in FM.

Reporting Dockage in Tenths of a Percent

Scientific blending procedures allow grain merchandisers to combine high-dockage sorghum lots with cleaner lots, thereby bringing both lots under the 1-percent ceiling. During 1988-92, only one of the 2,022 sorghum lots inspected for export had dockage levels exceeding 1 percent under the current dockage recording/reporting system, even though the actual dockage level averaged 0.31 percent. Only 80 samples (out of 2,022) had dockage levels of 0.6 percent or more.

Dockage is low, but not inconsequential. If dockage had been reported in tenth-percents during 1988-92, with penalties imposed for any reported dockage, average annual exports of 217 million bushels per year would have been reduced by 0.7 million bushels. This quantity reduction would have resulted in $1.4 million per year loss to sorghum exporters at a sorghum price of $2 per bushel, or $7 million over the 5-year period. Or, put in the opposing context, sorghum importers were charged $7 million over this 5-year period for 3.5 million bushels of nongrain material.[20]

[20]If dockage were reported in tenth-percents, it is very likely that a trigger mechanism would be instituted such that only dockage in excess of a given percentage level would be subject to penalty. If dockage had been reported in tenth-percents during 1988-92, with a trigger at 0.5 percent (dockage in excess of 0.5 percent penalized), then only 77,300 bushels of sorghum would have been subject to penalty during this time period, with over 70 percent of that total during 1989.

Reporting dockage in tenth-percents would benefit sorghum end-users, primarily feed manufacturers and importers, with costs passed back through the marketing channel to producers and intermediate handlers. It is clearly a more accurate measure and provides further quality information to the market. However, opposition to reporting dockage in tenths of a percent exists, because a new variable would be introduced into sorghum marketing. One of the intriguing aspects of reporting dockage in tenths of a percent is that sophisticated blending practices would have no effect on grade levels and little effect on price discounts (except in the hundredths-percent column). When two lots of different dockage levels are mixed, the reported dockage simply becomes the weighted average of the two. Because of this outcome and the fact that costs would be borne solely by suppliers, there are those who favor combining dockage with FM rather than reporting actual dockage levels.

Combining Dockage and Foreign Material

A second option for changing the way dockage is reported is to create a new factor, foreign material plus dockage (FMDK), by combining material currently defined as dockage (measured in tenths of a percent) with foreign material in the grading standards. Combining dockage and FM would raise the average level of FM in 1988-92 export sorghum from 1.6 to 1.9 percent, and the average level of BNFM from 5.4 to 5.7 percent. The cumulative frequency distributions for FM and BNFM (fig. 2) would shift to the left, and rejection rates based on the new factors would rise accordingly. Applying a 7/2.5 BNFMDK/FMDK standard to 1988-92 export sorghum samples results in the rejection rates presented in table 10. The failure rate of 18.0 percent with the 7/2.5 BNFMDK/FMDK standard is more than double the failure rate of the current standard. Likewise, the 7/2 BNFMDK/FMDK rejection rate is more than double the 7/2 BNFM/FM rate. Tightening the BNFM and BNFMDK factors (6/2.5 and 6/2) results in a 50-percent increase in rejection rates for the BNFMDK/FMDK standard over the BNFM/FM standard.

Table 10--Rejection rates for dockage combined with FM

FMDK level	BNFMDK level 7.0	6.0	5.0	4.0
	Percent			
2.5	18.0	38.9	73.7	93.6
2.0	37.4	47.5	74.5	93.7
1.5	70.8	72.0	79.3	94.0
1.0	93.0	93.0	93.3	96.4

The 8.3-percent failure rate obtained above is broken down into 4.0 percent failing the 7-percent BNFM standard, 5.3 percent failing the 2.5-percent FM standard, and 1 percent failing

both. The 18.0-percent failure rate for the combined 7/2.5 BNFMDK/FMDK standard has 10.2 percent failing the 7-percent BNFMDK standard, 12.1 percent failing the 2.5-percent FMDK standard, and 4.4 percent failing both standards. That is, both BNFM and FM are affected in similar fashion by combining dockage with FM.

If dockage were to be combined with foreign material in the grading standards, instead of blending to keep dockage below 1 percent, merchants would strive to keep FMDK below some threshhold level. If this threshhold level were held at 1 percent, then blending would become even more important as a marketing tool. In addition, a reported FMDK level necessarily larger than a reported FM level would increase the quantity of sorghum failing to meet U.S. No. 2 grade or better, resulting in price reductions for lower-grade sorghum. Again, blending high- and low-FMDK lots would be necessary for merchants to avoid lower-grade penalties. If changes are to be made in the way dockage is reported, then sellers would clearly prefer combining dockage with FM rather than having dockage reported (and penalized) in tenths of a percent.

Buyers, on the other hand, would clearly prefer separate, distinct tenth-percent factor reporting of both FM and DK. The additional data provided to buyers under this reporting scheme gives them information on what portion of the nongrain material would be easily removable by simple screen cleaners (DK) and what portion is not (FM). Whether or not importers would purchase more U.S. sorghum if a more accurate disclosure of actual factor contents were made remains an open question.

Conclusions

Cleaning U.S. sorghum to stricter standards than the current 7-percent BNFM, 2.5-percent FM standard for U.S. No. 2 sorghum is not economically feasible under current market conditions. The costs of cleaning all marketed sorghum to meet a 5-percent BN, 2-percent FM standard for U.S. No. 2 sorghum at the lowest net-cost locations (primarily at country elevators) would exceed the benefits by $0.8 million per year. The costs of cleaning all export sorghum (assuming perfect knowledge of destinations of sorghum shipments) to meet this standard would exceed the benefits by $0.5 million per year.

The additional net cost of cleaning sorghum such that all sorghum passes the 5-2 standard amounts to 1.1 cents per bushel of sorghum cleaned, and the additional net cost of cleaning only export sorghum such that all export sorghum passes the 5-2 standard amounts to 0.7 cent per bushel of sorghum cleaned. However, because a good proportion of sorghum does not need cleaning, the additional net costs per bushel of marketed sorghum are much smaller, approximately 0.2 and 0.1 cent, respectively, for cleaning all marketed sorghum and export sorghum to only the 5-2 standard. These per-bushel net costs are much smaller than for corn, where breakage occurs during handling and cleaning must take place at each point in the marketing channel.

Costs and benefits of additional sorghum cleaning may be quite different for individual commercial elevators. Elevators vary in size and location; in the number and type of

producers they buy sorghum from; and in the number and type of buyers they serve. Depending on the practices of the elevator, per-unit costs and benefits may be greater or less than those reported in this study.

End-users of sorghum seldom offer premiums for cleaner sorghum in the domestic market. Thus, any incentives in terms of premiums for cleaner sorghum must come from foreign buyers to justify additional cleaning. Selling cleaner U.S. sorghum in the international market would likely not result in additional sales, but could help to maintain U.S. market shares. It is not likely that U.S. merchants can make inroads into new markets. Corn provides the major competition for sorghum in export markets, and sorghum gains depend on corn market conditions, especially changes in the corn-to-sorghum price ratio.

The bulk of U.S. sorghum exports are used for livestock and poultry feed. Cleanliness and overall quality are less important than price differentials in these markets. Feed manufacturers are tolerant of broken kernels in sorghum, because nutritional integrity is largely unchanged, but are less well disposed to high levels of foreign material and dockage.

If lower BNFM or FM levels are to be achieved for export, the bulk of the additional cleaning would be undertaken at country elevators, with increasing amounts of cleaning at terminal and port elevators for ever-tighter standards. Because of fairly sophisticated blending practices, export elevators seldom find it necessary under the current standards to clean specific lots of sorghum to avoid grade and price discounts.

Policy options considered in this study for improving the cleanliness of U.S. sorghum are limited to changes in U.S. grades and standards. Separating BNFM into BN and FM factors (while holding the sum of the two factors constant) is not a particularly attractive option, since rejection rates would rise substantially. Reducing the maximum BNFM or FM levels (while maintaining FM as an explicit subfactor) would also result in considerably higher failure rates. Reporting (and penalizing) dockage in tenths of a percent instead of whole truncated percents would likely result in a substantial loss of revenue ($1.5 million per year during 1988-92) to the U.S. sorghum export industry. If changes are to be made in U.S. sorghum standards, a better alternative is to add dockage to foreign material, and use the resulting FMDK levels as a grade-determining factor. This change would improve the quality of U.S. export sorghum with much lower costs to market participants.

Glossary

Aeration--The passage of air through the grain mass (usually with fans) to control the adverse effects of excessive moisture, temperature, and humidity.

Aspirator--A device that draws a column of high velocity air across a flowing grain stream to separate low density materials (foreign material, chaff, insects) from the grain kernels. The air pressure is based on the weight of the sorghum. An aspirator can operate at a higher throughput capacity than screen cleaners but may result in a higher sorghum loss. Aspirators are generally used to remove low density materials such as chaff and dead insects.

Blending--The systematic combining of two or more lots of grains with different characteristics to obtain a uniform mixture of a desired specification.

Broken kernels (BN)--All matter that passes readily through a 5/64-inch, triangular-hole sieve and remains on top of a 2.5/64-inch, round-hole sieve according to procedures described in the U.S. Department of Agriculture's Federal Grain Inspection Service instructions.

Broken kernels and foreign material (BNFM)--All matter other than dockage that passes through a 5/64-inch triangular-hole sieve and all matter other than sorghum that remains in the sieved sample.

Cleanliness--The level of broken sorghum, foreign material, or dockage in sorghum.

Disc-cylinder cleaner--Removes dockage and small particles (such as weed seed) on the basis of particle shape and length. Grain passes through the middle of a horizontal revolving cylinder, which has small indentations in the metal. Smaller material falls into the indentations and is lifted as the cylinder revolves. As the material approaches the top of the cylinder, the material falls. Depending on the length of the material, it falls either into the dockage compartment or the grains compartment of the cleaner. Disc-cylinder cleaners are generally the most effective means to attain a low dockage level. However, their throughput capacity is generally less than other types of cleaners.

Discount--Reductions from the base price offered for grain. Generally calculated for factors that lower the value of the grain. May be expressed as percentage of price or as fixed amount per bushel. Serve as a disincentive for selling grain below the quality of the base grade.

Dockage--Any material that passes through a 2.5/64-inch round-hole seive according to procedures described in FGIS instructions.

Foreign material (FM)--All matter other than sorghum that passes over a number 6 riddle (similar to a 12/64-inch round-hole sieve) and all matter other than sorghum that remains on top of a 5/64-inch, triangular hole sieve according to procedures described in FGIS instructions.

Grade--A number designation assigned to grain based on a pre-established set of criteria.

Grain grades and standards--Specific standards established for each grain that describe the physical characteristics of different lots. The grades and standards facilitate trade by permitting the purchase of grain without the need for visual inspection and testing by the buyer.

Intrinsic value--Characteristics critical to the end-use of grain. These are nonvisual and can only be determined by analytical tests. For example, the intrinsic quality of sorghum is determined by characteristics such as protein, starch content, hardness, and density.

Marketing channels--The agencies and institutions through which products are moved from their original producers to the final consumers in the marketing of grain. The market channel includes all of the stages from the farm to the final consumer of raw or processed products.

Moisture content--The amount of water in sorghum; measured by the weight of water as a percentage of total weight of the grain including water.

Nongrade-determining factors--Factors that influence the quality of grain, and must be reported as information whenever an official inspection is made, but which are not used in determining the numerical grade (e.g., moisture).

Premium--Increases from the base price offered for grain of higher quality characteristics than specified for the base grade. Generally calculated for factors that increase the value of the grain.

Screen cleaner--A series of angled perforated plates or wire screens that separates the grain from particles that are larger or smaller than the grain kernel. The screens may be stationary, shaked, or rotated. The screen cleaner removes BNFM on the basis of particle size. The screens may differ in size, but screen cleaners are generally used to remove large particles.

Screenings--The material removed from grain by means of mechanical cleaning devices. Screenings include broken kernels, whole-kernel sorghum, and nongrain material removed on the basis of density or particle size.

Test weight--A measure of grain density determined by weighing a prescribed quantity of grain using methods prescribed in the U.S. grades and standards. Test weight has always been a sorghum grading factor, and it is related to density of the grain mass. It is influenced by many factors, such as maturity of the grain.

Weight loss--The percentage of small, salable sorghum kernels that are removed by the cleaner and/or broken by the motion of the cleaner itself.

References

Adam, B.D., and K.B. Anderson. *Costs and Benefits of Cleaning Hard Red Winter and Soft Red Winter Wheats.* A report submitted by Oklahoma State University to Economic Research Service under Cooperative Agreement No. 58-3AEK-0-80092. Dept. of Agri. Econ., Oklahoma State University, Oct. 1992.

Ash, M.S., and W.W. Lin. *Economic Impacts of Separating and Tightening the Combined Limits on Broken Kernels and Foreign Material for Sorghum.* A report submitted by Comm. Econ. Div., Econ. Res. Serv., U.S. Dept. Agri. to Fed. Grain Insp. Serv., U.S. Dept. Agri., July 1989.

Bello, H., W.R. Grant, and S.W. Fuller. *Cleaning Sorghum: Who Pays the Cost?* A report submitted by Texas A&M University to Economic Research Service under Cooperative Agreement No. 43-3AEK-1-80139. Technical Report No. 93-1, Dept. of Agri. Econ., Texas A&M University, College Station, 1993.

Brethour, J.R. "Aspirated Wheat and Milo Liftings in Cattle Growing Rations." Unpublished manuscript, Kansas Agri. Exp. Sta., Manhattan, 1987.

Feedstuffs. "Ingredient Market." Vol. 65(39), p. 24, Sept. 20, 1993.

Fridirici, R., H.L. Kiser, L.D. Schnake, and J. Wingfield. "A View on the Economics of Removing Dockage from Wheat." Unpublished manuscript, Kansas Agri. Exp. Sta., Manhattan, 1984.

Grant, W.R., and F. Cooke, "Recent Changes in the Competitive Position for U.S. Grain Sorghum Growing Areas," *Feed: Outlook and Situation Report.* FDS-299, U.S. Dept. Agri., Econ. Res. Serv., Mar. 1986.

Grant, W.R., S.W. Fuller, and H. Bello. *Costs of Cleaning U.S. Sorghum.* A report submitted by Texas A&M University to Economic Research Service under Cooperative Agreement No. 43-3AEK-1-80139. Technical Report No. 93/93-1, Dept. of Agri. Econ., Texas A&M University, College Station, 1992.

Hill, L.D., K.D. Bender, and K.D. Beachy. "Cost and Benefits of Cleaning Grain." Unpublished manuscript, Dept. of Agri. Econ., University of Illinois, July 1993.

Hill, L.D., M.G. Patterson, J.E. Vercimak, S.W. Fuller, and D.G. Anderson. *Sorghum Movements in the United States: Interregional Flow Patterns and Transportation Requirements in 1985.* North Central Regional Research Bulletin 322, Agri. Exp. Sta., College of Agriculture, University of Illinois, Urbana-Champaign, September 1990.

Jackson, D.M., W.R. Grant, and C.E. Shafer. *U.S. Sorghum Industry.* AER-457. U.S. Dept. Agri., Econ. Res. Serv., June 1980.

Lin, C.Z., and W.W. Lin. *Economic Implications of Cleaning Corn in the United States.* U.S. Dept. Agri., Econ. Res. Serv., AER-686, June 1994.

Lin, W.W., and L.A. Hoffman. *Sorghum: Background for 1990 Farm Legislation.* Staff Report No. 89-67, U.S. Dept. Agri., Econ. Res. Serv., Dec. 1989.

Mercier, S. *The Role of Quality in Corn Import Decisionmaking.* U.S. Dept. Agri., Econ. Res. Serv., AER-684, June 1994.

North American Export Grain Association. *Commitment to Grain Quality: A Consensus Report of the Grain Quality Workshops.* Washington, D.C., June 1986.

Riggs, J.K. *Utilization of Sorghum Grain by Livestock.* PR-2946, Texas Agri. Exp. Sta., College Station, Apr. 1971.

Scherping, D.J., D.W. Cobia, D.D. Johnson, and W.W. Wilson. *Wheat Cleaning Costs and Grain Merchandising.* Agri. Econ. Report No. 282, Dept. of Agri. Econ., North Dakota State University, Fargo, Feb. 1992.

U.S. Congress, Office of Technology Assessment. *Enhancing the Quality of U.S. Grain for International Trade.* OTA-F-399, Feb. 1989.

____________________. *Enhancing the Quality of U.S. Grain for International Trade: Summary.* OTA-F-400, Feb. 1989.

____________________. *Grain Quality in International Trade: A Comparison of Major U.S. Competitors.* OTA-F-402, Feb. 1989.

U.S. Department of Agriculture, Economic Research Service. *PS&D View '92: Users Manual and Database.* 1992.

____________________, Federal Grain Inspection Service. "Final Rule," *Federal Register.* Vol. 57(240):Dec. 14, 1992, pp. 58967-58972.

____________________. "General Information," *Grain Inspection Handbook, Book II.* 1990.

____________________. "Proposed Rule," *Federal Register.* Vol. 56(63):Apr. 2, 1991, pp. 13420-13424.

____________________. *1988 U.S. Grain Exports: Quality Report.* 1989.

____________________. *1989 U.S. Grain Exports: Quality Report.* 1990.

____________________. *1990 U.S. Grain Exports: Quality Report.* 1991.

______________________. *1991 U.S. Grain Exports: Quality Report*. 1992.

______________________. *1992 U.S. Grain Exports: Quality Report*. 1993.

______________________, Foreign Agricultural Service. *U.S. Export Sales*. Various issues, 1989-1993.

______________________. *Grain: World Markets and Trade*. Circular Service FG 3-94, Mar. 1994.

______________________, National Agricultural Statistics Service. *Agricultural Statistics, 1992.*

______________________. *Agricultural Prices, 1992 Summary*. July 1993.

Watson, Stanley A. "Measurement and Maintenance of Quality," *Corn: Chemistry and Technology*. Eds.: S.A. Watson and P.E. Ramstad, 1987.

Ziari, H.A., S.W. Fuller, W.R. Grant, and V. Sutaria. *Effect of Proposed Grain Standards on Marketing System Costs: The Sorghum Marketing System.* A report submitted by Texas A&M University to Economic Research Service under Cooperative Agreement No. 43-3AEK-1-80139. Technical Report No. 93-2, Dept. of Agri. Econ., Texas A&M University, College Station, 1993.

Appendix A: Cleaning Equipment Needs

Characteristics of U.S. grain elevators were obtained from a 1991 survey conducted by the National Grain and Feed Association. Summary characteristics obtained from this survey are reported in appendix table A-1. These characteristics serve as limitation parameters on the estimation of equipment needs by type of facility.

Onfarm

Only a few responses were obtained from the National Grain and Feed Association elevator survey and the University of Illinois farm practices survey regarding onfarm facilities for storing and cleaning sorghum. An onfarm storage facility with a 100,000-bushel volume was assumed. The FGIS data indicate that this farm would need to clean about 3,200 bushels (3.2 percent of its 0.1 MB volume) with the 8-percent BNFM standard; 10,800 bushels under the 7/2.5 standard; 19,600 bushels under the 5-2 standard; and 53,000 bushels under the 4-1 standard. A rotary screen cleaner costing $24,185 for the machine and an additional $24,185 for installation would be needed for the average onfarm storage facility cleaning grain during storage (app. table A-2). This cleaner, with a rated capacity of 500 bushels per hour (BPH), could handle the cleaning needs for the average onfarm storage facility cleaning during storage under all quality assumptions. Annual use would range from 7 hours per year under the old standard to 151 hours per year under the most stringent standard. No cost estimates were made for cleaning onfarm at loadout.

Country Elevators

The grain elevator survey shows that country elevators handling sorghum had an average annual grain volume of 2.3 million bushels (MB) per elevator with a truck loadout capacity of 7,550 BPH (app. table A-2). The representative country elevator would need to clean 74,000 bushels (74 TB) under the 8-percent BNFM standard; 246 TB under the 7/2.5 standard; 446 TB under the 5-2 standard; and 1,205 TB under the 4-1 standard. A 2,000 BPH rotary screen cleaner, costing $138,684 for the machine and installation, would be needed for the average country elevator cleaning grain during storage (app. table A-2), with annual usage ranging from 40 to 861 hours per year under the four quality assumptions. For country elevators cleaning during loadout, two 5,000 BPH rotary screen cleaners costing $305,060 for purchase and installation would be needed to meet the 7,550 BPH loadout requirement. Annual use would range from 8 to 172 hours per year under the four standards. Note that even though annual use is small for the lower standards, this size system would still be needed to maintain the average loading capacity of a country elevator. Under the most demanding standard, the system would have to exceed its rated limits.

Terminal Elevators

Terminal elevators with an average annual grain volume of 18.5 MB would need to clean about 592 TB with the 8-percent BNFM standard; 1,998 TB under the 7/2.5 standard; 3,626 TB under the 5-2 standard; and 9,805 TB under the 4-1 standard. To maintain the 24,204

Appendix table A-1--Grain elevator characteristics, 1990

Item	Unit	Elevator type: Country	Terminal	Port
Elevators with detailed sorghum schedule:				
Observations	No.	96	14	n.a.
Volume handled:				
Wheat	Bu.	457,718	11,268,562	n.a.
Corn	Bu.	810,429	2,547,071	n.a.
Soybeans	Bu.	183,902	753,481	n.a.
Sorghum	Bu.	819,461	5,798,068	n.a.
Barley	Bu.	2,269	0	n.a.
Total	Bu.	2,273,779	20,367,182	n.a.
Loadout capacity:				
Rail	BPH	6,540	27,428	n.a.
Truck	BPH	7,550	9,607	n.a.
Cleaning:				
Have cleaning eqpt.	Percent	36.8	92.9	n.a.
Can add cleaning eqpt.	Percent	28.9	21.4	n.a.
No. cleaning in 1990	Percent	3.9	7.1	n.a.
Percent sorghum cleaned	Percent	6.4	5.0	n.a.
Average cleaning cost	$/Bu.	.03	.05	n.a.
Average BNFM removed	#/cwt	1.1	2.2	n.a.
All elevators reporting:				
Observations	No.	821	45	13
Volume handled:				
Wheat	Bu.	2,370,186	7,484,329	35,334,846
Corn	Bu.	1,324,949	4,659,917	15,667,154
Soybeans	Bu.	582,148	4,064,935	12,178,545
Sorghum	Bu.	182,852	2,326,450	6,094,231
Barley	Bu.	61,360	7,798	1,935,308
Total	Bu.	4,521,495	18,543,429	71,210,084
Loadout capacity:				
Rail	BPH	6,098	24,204	16,154
Truck	BPH	7,821	11,668	5,423
Barge	BPH	0	1,622	6,923
Ship	BPH	0	0	36,923
Cleaning:				
Have cleaning eqpt.	Percent	58.8	86.7	84.6
Can add cleaning eqpt.	Percent	37.0	28.9	38.5

n.a. = not available.

Appendix table A-2--Cleaning equipment needs by type of elevator

Item	Unit	Standard			
		Old	7/2.5	5-2	4-1
Onfarm facilities:					
Grain handled	MB	0.1	0.1	0.1	0.1
Percent cleaned	Percent	3.2	10.8	19.6	53.0
Grain cleaned	TB	3.2	10.8	19.6	53.0
Cleaned during storage:					
Investment cost	$	24,185	24,185	24,185	24,185
Installment cost	$	24,185	24,185	24,185	24,185
Rated capacity	BPH	500	500	500	500
Throughput	BPH	450	425	400	350
Annual use	Hours	7	25	49	151
Country elevator:					
Grain handled	MB	2.3	2.3	2.3	2.3
Percent cleaned	Percent	3.2	10.8	19.6	53.0
Grain cleaned	TB	73	246	446	1205
Cleaned during storage:					
Investment cost	$	69,342	69,342	69,342	69,342
Installment cost	$	69,342	69,342	69,342	69,342
Rated capacity	BPH	2,000	2,000	2,000	2,000
Throughput	BPH	1,800	1,700	1,600	1,450
Annual use	Hours	40	144	279	861
Cleaned at unload/load:					
Loading capacity	BPH	7,550	7,550	7,550	7,550
Investment cost	$	152,530	152,530	152,530	152,530
Installment cost	$	152,530	152,530	152,530	152,530
Rated capacity	BPH	10,000	10,000	10,000	10,000
Throughput	BPH	9,000	8,500	8,000	7,000
Annual use	Hours	8	29	56	172

continued--

Appendix table A-2--Cleaning equipment needs by type of elevator (continued)

Item	Unit	Standard Old	7/2.5	5-2	4-1
Terminal elevator:					
Grain handled	MB	18.5	18.5	18.5	18.5
Percent cleaned	Percent	3.2	10.8	19.6	53.0
Grain cleaned	TB	593	2003	3634	9828
Cleaned during storage:					
Investment cost	$	165,146	165,146	165,146	165,146
Installment cost	$	165,146	165,146	165,146	165,146
Rated capacity	BPH	20,000	20,000	20,000	20,000
Throughput	BPH	18,000	17,000	16,000	14,000
Annual use	Hours	33	118	227	702
Cleaned at unload/load:					
Loading capacity	BPH	24,204	24,204	24,204	24,204
Investment cost	$	317,676	317,676	317,676	330,292
Installment cost	$	317,676	317,676	317,676	330,292
Rated capacity	BPH	30,000	30,000	30,000	40,000
Throughput	BPH	27,000	25,500	24,000	28,000
Annual use	Hours	22	78	151	351
Port elevator:					
Grain handled	MB	71.2	71.2	71.2	71.2
Percent cleaned	Percent	3.2	10.8	19.6	53.0
Grain cleaned	TB	2,279	7,691	13,957	37,741
Cleaned at unload/load:					
Loading capacity	BPH	36,923	36,923	36,923	36,923
Investment cost	$	406,557	406,557	406,557	495,438
Installment cost	$	406,557	406,557	406,557	495,438
Rated capacity	BPH	45,000	45,000	45,000	60,000
Throughput	BPH	40,500	38,250	36,000	42,000
Annual use	Hours	56	201	388	899

BPH loadout capacity, the average terminal elevator would need a system of two 5,000 BPH machines and one 20,000 BPH machine under each of the first three standards (app. table A-2). This system would cost $635,352 for the machinery and installation, and would run 22, 78, and 151 hours per year under the old standard, the new standard, and the 5-2 standard, respectively. The more demanding standard would require two 20,000 BPH cleaners, costing $660,584 for equipment and installation and running 351 hours per year. The average terminal elevator cleaning sorghum during storage would need only one 20,000 BPH machine at a cost of $330,292 for purchase and installation, with use ranging from 33 to 702 hours per year under the four standards.

Port Elevators

Port elevators with an average annual grain volume of 71.2 MB would need to clean about 2,278 TB with the 8-percent BNFM standard; 7,690 TB under the 7/2.5 standard; 13,955 TB with the 5-2 standard; and 37,736 TB with the 4-1 standard (app. table A-2). Port elevators, with limited storage capacity and a necessity to move grain rapidly through the facility, do not typically have the option of cleaning during storage. To maintain the 36,923 BPH loadout capacity, the average port elevator would need two 20,000 BPH screen cleaners and one 5,000 BPH cleaner under the first three standards (app. table A-2), at a cost of $813,114 for the equipment and installation. Annual usage would range from 56 to 388 hours for the old standard and the 5-2 standard. For the 4-1 standard, three 20,000 BPH cleaners would be needed, at a cost of $990,876 for equipment and installation and an expected annual usage of 899 hours.

Appendix B: Factor Prices and Input Parameters for Calculating Fixed and Variable Costs in the Economic Engineering Model

Factor levels assumed for calculating fixed and variable costs for cleaning sorghum onfarm and at country, terminal, and port elevators are presented in appendix table B-1. Except for labor costs, factor prices were assumed constant across all four locational types. The price of sorghum and the value of sorghum screenings also differed by location.

Fixed Costs

Fixed costs include depreciation, interest on investment, insurance, and taxes. Straight line depreciation with an interest rate of 12 percent and an expected life of 20 years was assumed. Annual depreciation calculated in this fashion is not substantively different from the fully amortized 20-year annual payment associated with a loan amount equal to the asset value (machinery purchase plus installation). Interest was calculated for only the machinery purchase price. Insurance expense was estimated to be $3.50 per $1,000 of investment and taxes were estimated to be $1 per $100 of investment.

Variable Costs

Variable costs include wages and salaries, electricity, maintenance and repairs, handling loss, weight loss, and interest on working capital. One hour of labor per hour of cleaner operation was assumed for each cleaner with a rated capacity less than 10,001 bushels per hour, with larger capacity machines requiring 2.5 hours of labor per hour of cleaning activity. Supervisory labor was estimated to be 0.1 hour per hour of cleaning at all elevator types. Per hour wage rates by elevator type are shown in appendix table B-1. Electricity cost estimates were based on the average equipment operating time and an estimated electricity cost of $0.105 per kilowatt hour. Annual maintenance and repair costs include daily maintenance and replacement and installation of failed equipment. These costs were computed at 3 percent of machinery cost per 1,000 hours of operation plus maintenance labor at 0.5 hour per 40 hours of machinery operation.

Handling loss occurs only when grain is cleaned during storage. This loss was estimated as 0.1 percent of grain volume. Grain that is cleaned during loadout or unload would also experience handling loss, but it cannot be attributable to the cost of cleaning since it would have occurred regardless of cleaning. Working capital needs for grain cleaning were calculated as the sum of wages, electricity, maintenance, repairs, and grain loss. These costs were prorated across 3-months' interest charge.

Weight loss occurs during the cleaning process when good grain passes through the filters along with the brokens and foreign material. This grain is then sold as screenings. Screenings have economic value as livestock feed. Proximity to feed manufacturers or feeding areas increases this value (relatively), due to lessened transportation and handling costs. The weight loss was calculated as the quantity of grain removed with the screenings (percentage of good grain in screenings times percentage of screenings extracted) multiplied

Appendix table B-1--Factor levels assumed by type of elevator

Item	Unit	Onfarm	Country	Terminal	Port
Interest rate	Percent	12	12	12	12
Handling loss	Percent	.1	.1	.1	.1
Operator labor	$/hr	6	6	13	20
Supervisor labor	$/hr	13	13	20	35
Electricity rate	$/KW	.105	.105	.105	.105
Weight loss:[1]					
8% BNFM	Percent	.19	.19	.19	.19
7% BNFM, 2.5% FM	Percent	.23	.23	.23	.23
5% BN, 2% FM	Percent	.28	.28	.28	.28
4% BN, 1% FM	Percent	.37	.37	.37	.37
Insurance rate	$/$1,000	3.50	3.50	3.50	3.50
Tax rate	$/$100	1.00	1.00	1.00	1.00
Repair cost/1,000 hrs.	Factor	.03	.03	.03	.03
Sorghum price	$/bu	2.10	2.10	2.40	2.80
Screenings price	$/bu	1.12	1.12	.88	.76

[1]Weight loss percentages based on 9-percent sorghum in screenings and screenings extractions percentages of 2.1, 2.5, 3.1, and 4.1, respectively, for 8% BNFM; 7% BNFM, 2.5% FM; 5% BN, 2% FM; and 4% BN, 1% FM.

by the difference between the value of grain and the value of screenings. A figure of 9-percent sorghum in screenings was used, based on wheat screenings data and an assumed comparability between wheat and sorghum. Screenings-extracted percentages increased with tighter standards and ranged from 2.1 to 4.1 percent. Country elevator sorghum screenings were valued the same as wheat at $2 per hundredweight, or $1.12 per sorghum-equivalent bushel. Terminal elevators were assumed to have an average 200-mile market range for their screenings, with a rail transportation cost of $0.24 per bushel, resulting in an f.o.b. price at terminal elevators of $0.88 per sorghum equivalent bushel. Similarly, port elevators were assumed to have an average 400-mile market radius for screenings and an average $0.36-per-bushel transportation cost, reducing the f.o.b. port elevator price for sorghum screenings to $0.76 per sorghum-equivalent bushel.

Appendix C: Economic Engineering Estimates of Fixed and Variable Costs of Cleaning Sorghum

Fixed and variable cost estimates for cleaning sorghum to the four standards at the four locations in the marketing chain are shown in appendix table C-1. Cost estimates are given for the average size elevator for each location. Six sets of cost estimates for cleaning sorghum are provided: cleaning during storage on farms, at country elevators, and at terminal elevators; and cleaning during unloading or loadout at country, terminal, and port elevators. Both total and per-bushel fixed and variable costs are reported. Appendix table C-2 lists the items included in variable cost calculations as percentages of total variable cost. Fixed cost component percentages are presented at the bottom of appendix table C-2. Fixed cost items are constant percentages at all locations for all grade standards. Approximately one-half of fixed costs is interest payments, 42 percent is depreciation, and 7 percent of the total is insurance and taxes.

Onfarm Storage Facilities

The annual fixed cost for onfarm storage facilities totals $5,732 and is constant over all grade standards. With the increased volume being cleaned with the lower limits, however, per-bushel fixed cost ranges from $1.79 under the old grade standard to 10.81 cents with the strictest standard considered. Labor accounts for nearly two-thirds of onfarm variable costs. The weight loss percentage is the only component that increases with tighter cleaning standards. Per-bushel variable costs at the onfarm storage facility fell in a narrow range, from 2.46 cents per bushel under the old standard to 3.24 cents per bushel with the strictest standard. Total cost is heavily influenced by fixed cost when the cleaning volume is low. Total cleaning cost per bushel amounted to $1.82 with the old standard (3,200 bushels cleaned annually); 55.6 cents per bushel under the current standard (10,800 bushels); 32.1 cents per bushel with the FGIS proposed standard (19,600 bushels); and 14.1 cents per bushel with the more demanding standard (53,000 bushels cleaned).

Country Elevators

Per-bushel costs fall dramatically when cleaning is undertaken further up the marketing chain. Per-bushel costs for cleaning during storage at the average country elevator were calculated as 23.7 cents per bushel with the old standard (72,768 bushels cleaned); 7.8 cents per bushel under the current standard (245,592 bushels); 4.9 cents per bushel with the 5-2 standard (445,704 bushels); and 2.8 cents per bushel under the 4-1 standard (1,205,220 bushels cleaned). Costs increased somewhat when cleaning was undertaken during receiving or loadout: 50.0, 15.1, 8.6, and 3.6 cents per bushel for the four standards, respectively. Fifteen country elevators in the National Grain and Feed Association elevator survey reported an average cleaning cost of 3.64 cents per bushel.

Fixed costs again dominated the calculations, exceeding variable costs per bushel for all but one of the eight calculations. Fixed costs ranged from 22.6 cents to 1.4 cents per bushel when cleaning was undertaken during storage, and from 49.7 to 3.0 cents per bushel during

Appendix table C-1--Aggregate and per-bushel fixed and variable costs by elevator type and method of cleaning

Item	Unit	Cleaned during storage			
		8% BNFM	7% BNFM 2.5% FM	5% BN 2% FM	4% BN 1% FM
On-farm facilities:					
Total cost	$	5,810	6,002	6,283	7,447
Fixed	$	5,732	5,732	5,732	5,732
Variable	$	79	270	551	1,715
Total cost	¢/bu	181.58	55.57	32.06	14.05
Fixed	¢/bu	179.12	53.07	29.24	10.81
Variable	¢/bu	2.46	2.50	2.81	3.24
Total cleaned	TB/yr	3.2	10.8	19.6	53.0
Country elevators:					
Total cost	$	17,207	19,250	21,984	33,823
Fixed	$	16,434	16,434	16,434	16,434
Variable	$	777	2,816	5,550	17,389
Total cost	¢/bu	23.65	7.84	4.93	2.81
Fixed	¢/bu	22.58	6.69	3.69	1.36
Variable	¢/bu	1.06	1.15	1.25	1.44
Total cleaned	TB/yr	72.8	245.6	445.7	1,205.2
Terminal elevators:					
Total cost	$	44,234	58,133	77,474	161,853
Fixed	$	39,140	39,140	39,140	39,140
Variable	$	5,095	18,993	38,335	122,714
Total cost	¢/bu	7.45	2.90	2.13	1.65
Fixed	¢/bu	6.60	1.95	1.08	.40
Variable	¢/bu	.86	.95	1.05	1.25
Total cleaned	TB/yr	593.4	2,002.6	3,634.4	9,827.8

continued--

Appendix table C-1--Aggregate and per-bushel fixed and variable costs by elevator type and method of cleaning (continued)

Item	Unit	Cleaned at unload/loadout			
		8% BNFM	7% BNFM 2.5% FM	5% BN 2% FM	4% BN 1% FM
Country elevators:					
Total cost	$	36,389	37,091	38,145	42,926
Fixed	$	36,150	36,150	36,150	36,150
Variable	$	240	942	1,995	6,776
Total cost	¢/bu	50.01	15.10	8.56	3.56
Fixed	¢/bu	49.68	14.72	8.11	3.00
Variable	¢/bu	.33	.38	.45	.56
Total cleaned	TB/yr	72.8	245.6	445.7	1,205.2
Terminal elevators:					
Total cost	$	78,005	85,864	98,352	151,852
Fixed	$	75,289	75,289	75,289	78,279
Variable	$	2,715	10,575	23,063	73,573
Total cost	¢/bu	13.15	4.29	2.71	1.55
Fixed	¢/bu	12.69	3.76	2.07	.80
Variable	¢/bu	.46	.53	.63	.75
Total cleaned	TB/yr	593.4	2,002.6	3,634.4	9,827.8
Port elevators:					
Total cost	$	108,904	146,762	205,454	476,173
Fixed	$	96,354	96,354	96,354	117,419
Variable	$	12,550	50,408	109,100	358,754
Total cost	¢/bu	4.78	1.91	1.47	1.26
Fixed	¢/bu	4.23	1.25	.69	.31
Variable	¢/bu	.55	.66	.78	.95
Total cleaned	TB/yr	2,278.7	7,690.7	13,957.2	37,741.3

Appendix table C-2--Fixed and variable cost component percentages by elevator type and method of cleaning

Item	Cleaned during storage			
	8% BNFM	7% BNFM 2.5% FM	5% BN 2% FM	4% BN 1% FM
	Percent			
Fixed cost (all):				
Depreciation	42.2	42.2	42.2	42.2
Interest	50.6	50.6	50.6	50.6
Insurance	3.0	3.0	3.0	3.0
Tax	4.2	4.2	4.2	4.2
Onfarm facilities:				
Operator labor	54.3	53.3	53.3	53.0
Supervisor labor	11.8	11.5	11.6	11.5
Conveyance energy	3.8	3.7	3.7	3.7
Cleaning energy	4.3	4.2	4.2	4.2
Main/repair	7.2	7.1	7.1	7.1
Handling loss	8.5	8.4	7.5	6.5
Weight loss	7.2	8.8	9.7	11.2
Interest	2.9	2.9	2.9	2.9
Country elevators:				
Operator labor	31.4	30.8	30.1	29.7
Supervisor labor	6.8	6.7	6.5	6.4
Conveyance energy	8.8	8.6	8.4	8.3
Cleaning energy	2.5	2.4	2.4	2.3
Main/repair	11.3	11.1	10.8	10.7
Handling loss	19.8	18.3	16.9	14.6
Weight loss	16.6	19.2	22.0	25.1
Interest	2.9	2.9	2.9	2.9
Terminal elevators:				
Operator labor	21.0	20.2	19.3	18.6
Supervisor labor	1.3	1.2	1.2	1.1
Conveyance energy	10.9	10.4	10.0	9.6
Cleaning energy	.8	.7	.7	.7
Main/repair	3.3	3.2	3.0	2.9
Handling loss	28.0	25.3	22.8	19.2
Weight loss	31.9	36.1	40.2	44.9
Interest	2.9	2.9	2.9	2.9

continued--

Appendix table C-2--Fixed and variable cost component percentages by elevator type and method of cleaning (continued)

Item	Cleaned during unload/loadout			
	8% BNFM	7% BNFM 2.5% FM	5% BN 2% FM	4% BN 1% FM
	Percent			
Fixed cost (all):				
Depreciation	42.2	42.2	42.2	42.2
Interest	50.6	50.6	50.6	50.6
Insurance	3.0	3.0	3.0	3.0
Tax	4.2	4.2	4.2	4.2
Country elevators:				
Operator labor	20.2	18.4	16.8	15.2
Supervisor labor	4.4	4.0	3.6	3.3
Conveyance energy	0	0	0	0
Cleaning energy	3.2	2.9	2.6	2.4
Main/repair	15.7	14.3	13.0	11.8
Handling loss	0	0	0	0
Weight loss	53.6	57.5	61.1	64.3
Interest	2.9	2.9	2.9	2.9
Terminal elevators:				
Operator labor	26.3	22.8	21.3	15.5
Supervisor labor	1.6	1.4	1.3	1.0
Conveyance energy	0	0	0	0
Cleaning energy	1.5	1.3	1.2	.9
Main/repair	7.8	6.8	6.4	4.8
Handling loss	0	0	0	0
Weight loss	59.8	64.8	66.8	74.9
Interest	2.9	2.9	2.9	2.9
Port elevators:				
Operator labor	22.4	19.9	17.8	12.5
Supervisor labor	1.6	1.4	1.2	.9
Conveyance energy	0	0	0	0
Cleaning energy	.8	.8	.8	.7
Main/repair	5.6	5.0	4.4	3.8
Handling loss	0	0	0	0
Weight loss	66.7	70.0	72.8	79.2
Interest	2.9	2.9	2.9	2.9

unloading or loadout. The higher fixed costs at unload/loadout were due to increased equipment needs (see app. table A-2). In contrast to per-bushel fixed costs, variable costs per bushel were lower at unload/loadout than during storage, falling from 1.1, 1.2, 1.3, and 1.4 cents per bushel at unload/loadout to 0.3, 0.4, 0.5, and 0.6 cents per bushel during storage under the four standards. Handling losses and conveyance costs are absent when sorghum is cleaned at unload/loadout.

Labor cost decreases in importance at the country elevator compared with onfarm storage facilities, due largely to the increased costs associated with cleaning greater quantities of sorghum. Labor costs are just over one-third of total variable costs when grain is cleaned during storage, an amount approximately equal to losses attributed to cleaning and handling. When sorghum is cleaned at unload/loadout, the major cost factor is weight loss, ranging from 53.6 percent of variable costs under the old standard to 64.3 percent under the strictest standard. Labor costs are in the 20 to 25 percent range. Maintenance and repair are also substantial variable cost items.

Terminal Elevators

Labor costs continue to diminish in importance when sorghum is cleaned during storage at terminal elevators as opposed to country elevators. Labor cost percentages fall to the 20 to 22 percent range, while costs attributed to cleaning, handling, and conveyance rise to more than 70 percent of the variable cost of cleaning sorghum during storage. During unload/loadout, handling losses and conveyance costs are zero, so that weight losses range from 60 to 75 percent of variable costs under the four standards, and labor costs range from 17 to 28 percent of variable costs.

Fixed cost per bushel also decreases at terminal elevators compared with country elevators, again due to the increase in the volume cleaned. The volume cleaned at the average terminal elevator was calculated as 593 TB under the old standard, 2,003 TB under the current standard, 3,634 TB with the original FGIS proposal, and 9,828 TB under the more demanding standards. Fixed costs per bushel when cleaning during storage were at 6.6, 2.0, 1.1, and 0.4 cents per bushel for the respective grain standard assumptions. Total and per-bushel annual fixed costs for terminal elevators cleaning at loadout are at higher levels due to the need for higher capacity machines. However, fixed costs of 12.7, 4.8, 2.1, and 0.8 cents per bushel for the four standards are still lower than the comparable figures for cleaning during storage at country elevators.

Variable costs range from 0.33 to 0.56 cent per bushel for cleaning at unload/loadout and from 0.86 to 1.25 cents per bushel for cleaning during storage. Total per-bushel costs for cleaning sorghum at loadout were at 13.2 cents per bushel under the old standard; 4.3 cents per bushel under the current standard; 2.7 cents per bushel under the 5-2 standard; and 1.6 cents per bushel under the 4-1 standard. The total cost range is mostly lower when cleaning during storage at the terminal elevator: 7.5, 2.9, 2.1, and 1.7 cents per bushel for the four standards, respectively. Total cost is approximately equal under the strictest standard for cleaning during storage compared with unload/loadout.

Port Elevators

Although port elevators have limited storage capacity and do not have the option of cleaning grain during storage, their high volumes lead to the lowest cleaning cost calculations of any point in the marketing chain. The average port elevator would clean 2.3 MB, 7.7 MB, 14.0 MB, and 37.7 MB under the four standards. Total costs drop from 4.8 cents per bushel under the old standard to 1.9 cents per bushel under the current standard, and to 1.5 and 1.3 cents per bushel under the 5-2 and 4-1 standards. Fixed costs per bushel fall off even more dramatically with the high volumes cleaned, dropping from 88 and 65 percent of total costs under the old and the current standard, to 47 and 25 percent with the alternative standards. As above, variable costs rise with tighter standards, from 0.55 cent per bushel under the old standard to 0.66, 0.78, and 0.95 cent with the current and alternative standards. Weight loss dominates variable cleaning costs at the average port elevator, ranging from 66.7 to 79.2 percent of total variable cost.

Appendix D: Linear Programming Estimates of Costs and Revenues for Alternative Standards, Prices, and Scenarios

The cost-benefit section in the text focused on the additional costs and benefits associated with changing limits on U.S. No. 2 sorghum standards and on the cleaning locations and additional investment in cleaning equipment necessary to attain desired cleanliness levels. In this appendix, I present total system costs and revenues for the four cleanliness standards (8-percent BNFM; 7-percent BNFM, 2.5-percent FM; 5-percent BN, 2-percent FM; and 4-percent BN, 1-percent FM) under three scenarios (a baseline and two alternatives) and using three sorghum price levels ($1.70, $2.00, and $2.30), with sorghum screenings (in 56-pound-bushel measures) priced at 56 percent of the sorghum grain price level.

Under the baseline scenario, grain cleaning at country and terminal elevators is carried out while grain is in storage, whereas cleaning at port is accomplished at loadout. All marketed sorghum which does not meet the proposed standard must be cleaned and country elevators have capacity to store about 40 percent of the excess supply or surplus. The two alternative scenarios are each identical to the baseline except for a change in one assumption in each scenario. In the second scenario, country elevators are assumed to have adequate storage to carry regional surpluses. In the third scenario, only sorghum destined for foreign markets need meet the grade standard, while domestic demands are met by sorghum which may not meet the proposed standard. The cost-benefit results presented in the text focus on the baseline scenario and the second alternative.

The estimated total marketing costs for the sorghum industry for cleaning sorghum to the four cleanliness standards over the three scenarios under three sorghum price levels are presented in appendix table D-1. System costs include handling and transportation expenses, storage fees, fixed and variable costs for cleaning sorghum, and costs associated with marketing the screenings. Total and per-bushel costs and revenues associated with additional sorghum cleaning can be calculated by subtracting system costs (revenues) related to the current standard (7/2.5) from costs (revenues) associated with the alternative standards (5-2 and 4-1). Likewise, cost and revenue calculations can also be made for the move to the current standard from the old standard. It was assumed that equipment on hand would be sufficient for firms to clean to the old and current standard. Additional cleaning equipment is needed to clean sorghum to the other two standards.

Baseline Scenario

Under the current standard in the baseline scenario, nearly 40 MB, or 10.2 percent of the farmer-delivered grain, require cleaning (table 7). This is approximately three times the amount of cleaning required under the old standard. Cleaning under the current standard generates 1.2 million bushels of screenings, or 0.3 percent of all marketed sorghum (app. table D-1). The total system cost for marketing the 389.36 MB of clean sorghum is $317 million. Revenues range from $663 million when sorghum is priced at $1.70 per bushel to $897 million at $2.30 per bushel, resulting in net revenues of $346 million, $463 million, and $580 million for sorghum prices of $1.70, $2.00, and $2.30, respectively. Compared with the old

Appendix table D-1--System costs and revenues for alternative U.S. No. 2 sorghum standards and prices

Item	Scenario 1: Baseline			
	8% BNFM	7% BNFM 2.5% FM	5% BN 2% FM	4% BN 1% FM
	Million bushels			
Total clean sorghum	390.29	389.36	388.36	382.23
Screenings generated	.27	1.20	2.20	8.33
	$1,000			
System costs:				
Handling/transport	303,006	302,342	301,395	297,267
Storage	13,790	13,795	13,723	13,614
Cleaning cost	136	448	1,194	4,075
Marketing screenings	37	174	338	1,344
Total	316,970	316,760	316,650	316,300
System revenues:				
Sorghum at $1.70/bushel--				
Clean sorghum	663,493	661,912	660,212	649,791
Screenings	257	1,142	2,094	7,930
Total	663,750	663,054	662,306	657,721
Net revenue	346,780	346,294	345,656	341,421
Change from "prior" standard	n.a.	-486	-638	-4,873
Cost per marketed bushel	n.a.	-.0012	-.0016	-.0127
Sorghum at $2.00/bushel--				
Clean sorghum	780,580	778,720	776,720	764,460
Screenings	302	1,344	2,464	9,329
Total	780,882	780,064	779,184	773,790
Net revenue	463,912	463,304	462,534	457,490
Change from "prior" standard	n.a.	-608	-770	-5,814
Cost per marketed bushel	n.a.	-.0016	-.0020	-.0152
Sorghum at $2.30/bushel--				
Clean sorghum	897,667	895,528	893,228	879,129
Screenings	348	1,546	2,834	10,729
Total	898,015	897,074	896,062	889,858
Net revenue	581,045	580,314	579,412	573,558
Change from "prior" standard	n.a.	-731	-902	-6,756
Cost per marketed bushel	n.a.	-.0019	-.0023	-.0177

continued--

Appendix table D-1--System costs and revenues for alternative U.S. No. 2 sorghum standards and prices (continued)

Item	8% BNFM	7% BNFM 2.5% FM	5% BN 2% FM	4% BN 1% FM
	Scenario 2: Increased country elevator storage			
	Million bushels			
Total clean sorghum	390.29	389.36	388.36	382.23
Screenings generated	.27	1.20	2.20	8.33
	$1,000			
System costs:				
Handling/transport	278,118	277,559	276,502	272,056
Storage	16,609	16,566	16,546	16,486
Cleaning cost	136	443	1,265	4,066
Marketing screenings	37	185	307	1,183
Total	294,900	294,750	294,620	293,790
System revenues:				
Sorghum at $1.70/bushel--				
Clean sorghum	663,493	661,912	660,212	649,791
Screenings	257	1,142	2,094	7,930
Total	663,750	663,054	662,306	657,721
Net revenue	368,850	368,304	367,686	363,931
Change from "prior" standard	n.a.	-546	-618	-4,373
Cost per marketed bushel	n.a.	-.0014	-.0016	-.0114
Sorghum at $2.00/bushel--				
Clean sorghum	780,580	778,720	776,720	764,460
Screenings	302	1,344	2,464	9,329
Total	780,882	780,064	779,184	773,790
Net revenue	485,982	485,314	484,564	480,000
Change from "prior" standard	n.a.	-668	-750	-5,314
Cost per marketed bushel	n.a.	-.0017	-.0019	-.0139
Sorghum at $2.30/bushel--				
Clean sorghum	897,667	895,528	893,228	879,129
Screenings	348	1,546	2,834	10,729
Total	898,015	897,074	896,062	889,858
Net revenue	603,115	602,324	601,442	596,068
Change from "prior" standard	n.a.	-791	-882	-6,256
Cost per marketed bushel	n.a.	-.0020	-.0023	-.0164

continued--

Appendix table D-1--System costs and revenues for alternative U.S. No. 2 sorghum standards and prices (continued)

Item	8% BNFM	7% BNFM 2.5% FM	5% BN 2% FM	4% BN 1% FM
	Scenario 3: Cleaning for foreign markets only			
	Million bushels			
Total clean sorghum	390.34	389.71	389.08	385.77
Screenings generated	.22	.85	1.48	4.79
	$1,000			
System costs:				
Handling/transport	303,058	302,469	301,887	299,010
Storage	13,792	13,783	13,739	13,696
Cleaning cost	110	318	781	2,202
Marketing screenings	30	130	223	782
Total	316,990	316,700	316,630	315,690
System revenues:				
Sorghum at $1.70/bushel--				
Clean sorghum	663,578	662,507	661,436	655,809
Screenings	209	809	1,409	4,560
Total	663,787	663,316	662,845	660,369
Net revenue	346,797	346,616	346,215	344,679
Change from "prior" standard	n.a.	-181	-401	-1,937
Cost per marketed bushel	n.a.	-.0005	-.0010	-.0050
Sorghum at $2.00/bushel--				
Clean sorghum	780,680	779,420	778,160	771,540
Screenings	246	952	1,658	5,365
Total	780,926	780,372	779,818	776,905
Net revenue	463,936	463,672	463,188	461,215
Change from "prior" standard	n.a.	-264	-484	-2,457
Cost per marketed bushel	n.a.	-.0007	-.0012	-.0064
Sorghum at $2.30/bushel--				
Clean sorghum	897,782	896,333	894,884	887,271
Screenings	283	1,095	1,906	6,170
Total	898,065	897,428	896,790	893,440
Net revenue	581,075	580,728	580,160	577,751
Change from "prior" standard	n.a.	-348	-568	-2,977
Cost per marketed bushel	n.a.	-.0009	-.0015	-.0077

n.a. = not applicable.

standard, these additional costs for the current standard total $581,000 for a $1.70 sorghum price, $720,000 for a $2.00 sorghum price, and $860,000 for a $2.30 sorghum price. Per marketed bushel, the net effect has been an additional 0.15, 0.18, and 0.22 cent, respectively, for the three prices.

Cleaning to tighter standards results in additional net costs relative to the current standard. Total system marketing costs decrease as standards are tightened, due to lower transportation and handling costs. However, system revenues decrease by a greater amount, due to the lower clean grain volume. The additional cost per marketed bushel for the 5-2 standard relative to the current standard amounts to 0.19 cent per marketed bushel for a $1.70 sorghum price, 0.23 cent for a $2.00 price, and 0.27 cent for a $2.30 price. Additional costs for the 4-1 standard are 1.47, 1.75, and 2.02 cents per marketed bushel for the three prices, respectively. The total system net cost ranges from $740,000 to $1.04 million for the 5-2 standard and from $5.6 to $7.74 million for the 4-1 standard.

Scenario 2

Assumptions in the first alternative scenario are identical to the baseline except that country elevators are assumed to have adequate storage to carry regional surpluses. Cleaning levels and costs change little from the baseline in this scenario (app. table D-1). However, without the country elevator storage constraints, flow patterns are modified in two ways. Country elevators no longer need to transship sorghum through terminal elevators (where storage is plentiful), and more grain stored at country elevators moves directly to the Texas gulf ports by railroad. As a result, transportation and handling costs fall by about $25 million under each of the four standards, while storage costs rise by about $3 million due to the higher cost of storing grain at country elevators. All additional investment in cleaning capacity ($3.5 million under the 5-2 standard and $10.5 million under the 4-1 standard) is optimally located at country elevator locations.

Additional system costs of moving to the current standard from the old standard rise somewhat in this scenario compared with the baseline. Costs of additional cleaning for the current standard now range from $641,000 when the sorghum price is at $1.70 per bushel to $920,000 when the price is at $2.30 per bushel. The additional cost of moving to even tighter standards drops slightly in this scenario compared with the baseline, ranging from $720,000 to $1.02 million for the 5-2 standard, and from $5.1 million to $7.24 million for the 4-1 standard.

Scenario 3

Under this scenario it is assumed that only foreign demand is satisfied by sorghum that meets the various U.S. No. 2 standards under consideration, whereas domestic demand may be met by grain that may not meet cleanliness criteria. This scenario thus requires a lower level of cleaning activity, ranging from 80.6 percent of the baseline scenario level under the old standard to 57.6 percent under the 4-1 standard (tables 7-8). Total system costs are comparable between this scenario and the baseline (app. table D-1), but the greater quantity

marketed results in lower system costs per bushel under this scenario. In addition, the greater quantity of clean grain increases total revenues, resulting in higher net revenues and substantially lower additional cleaning costs in this scenario compared with the baseline. Costs of additional cleaning for the current standard now range from $245,000 when the sorghum price is at $1.70 per bushel to $581,000 when the price is at $2.30 per bushel. The additional cost of moving to tighter standards ranges from $346,000 to $580,000 for the 5-2 standard, and from $2.3 million to $3.5 million for the 4-1 standard.